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VETERINARY HELMINTHOLOGY AND ENTOMOLOGY

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VETERINARY HELMINTHOLOGY AND ENTOMOLOGY

THE DISEASES OF DOMESTICATED ANIMALS CAUSED BY HELMINTH AND ARTHROPOD PARASITES

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To

The Memory of

SIR ARNOLD THEILER

PREFACE TO THE THIRD EDITION

A FURTHER edition has been long overdue on account of much progress in veterinary parasitology, but was impossible to produce during the recent years of turmoil.

Numerous large and small alterations and additions have been made to the text and some new illustrations added. Of the latter the most important are plates of worm eggs of the different domestic animals which, I trust, will be of considerable practical value. In order to complete these egg-plates the co-operation of colleagues in various countries had to be sought and I, as well as users of this book, owe them our appreciation for their kind and willing assistance.

H. O. MÖNNIG.

PRETORIA, SOUTH AFRICA,
January, 1947.

PREFACE TO THE FIRST EDITION

SINCE the publication of Neumann's " Parasites and Parasitic Diseases of Domesticated Animals " in 1892 no textbook that deals adequately with the helminth and arthropod diseases of domesticated animals has appeared, although great progress in this subject can be recorded. Several very useful books have been written on the morphology of helminth and arthropod parasites, but the parasitic diseases with which the veterinarian is primarily concerned, and of which the parasites are only the ætiological factors, have received very little consideration.

During several years of teaching in these subjects the author has felt the great need of a suitable book for veterinary students and practitioners, and the present volume represents an attempt to supply that need. At the same time he hopes that this compilation of practical facts will serve to bring about a realisation of the importance of veterinary parasitology, which is still underrated in many quarters, and that the veterinary student should receive a more adequate training in it.

It has not been the intention to present a complete manual, in which the information required by the veterinarian is buried in a mass of detail, but to give in a scientific way the most important practical facts of the subject. Many known parasites of domesticated animals are not mentioned because they are rarely seen or because little is known about their pathogenicity. It has naturally been difficult to draw the line here, as well as between the hosts themselves. On the whole an attempt has been made to include the important parasites of all the important domesticated animals of all countries. The parasitic diseases of the fur-bearing animals have also been included, because this branch of livestock farming has assumed an importance that deserves the full attention of the veterinarian. If any important parasites of these animals have been omitted, it is only because discrimination on the subject is difficult at the present stage of our knowledge.

Original drawings have been made as far as possible and numerous measurements and morphological features have been checked on suitable material. Several textbooks, particularly " A Manual of Helminthology, Medical and Veterinary," by Baylis, and the " Medical Entomology " of Patton and Cragg, have been freely consulted for morphological data. It is a pleasant duty to express my indebtedness to a number of colleagues in various countries for supplying me with certain specimens and information. Among these must be mentioned particularly the Imperial Bureau of Agricultural Parasitology, Professors R. T. Leiper, C. Sprehn, and W. Nöller, Dr. P. A. Maplestone and Mr. G. B. Purvis. My best thanks are also due to several authors and publishers for allowing me to use their illustrations, to Messrs. C. G. Walker and A. B. M. Whitnall for making the drawings marked with their initials, to my wife for much assistance in various ways, and to the publishers for their excellent management and careful execution of the presswork.

H. O. MÖNNIG.

ONDERSTEPOORT, SOUTH AFRICA.
June, 1934.

CONTENTS

PAGES
Preface to the Second Edition - vii
Preface to the First Edition - ix
Introduction - xvii

SECTION I

GENERAL

1. Parasitism and Other Forms of Life - 2
2. Types of Parasitic Relations - 3
3. Pathogenicity and Pathogenic Effects - 4
4. Host and Organ Specificity - 5
5. Resistance and Immunity - 6
6. Effect of Parasitic Life on the Parasite - 8
7. Epizootology - 9
8. Geographic Distribution - 10
9. Historical - 10

SECTION II

TECHNIQUE

Collection and Preservation of Helminths - 13
Collection and Preservation of Arthropod Parasites - 14
Making of Permanent Preparations - 15
Clinical Diagnostic Methods - 16
  1. The Outside of the Body - 16
  2. Excretions - 16
    Fæces: (*a*) The Direct Smear; (*b*) Concentration Methods, the Willis Technique, Centrifugal Flotation; (*c*) Egg-Counting Technique; (*d*) Fæces Cultures - 16–26
  3. Blood Examination for Larvæ - 27
  4. Allergic Reactions - 28
    (i.) Intradermal Reactions; (ii.) Complement Fixation; (iii.) Precipitin Reaction - 28–29

SECTION III

HELMINTH PARASITES

Classification - 31
PHYLUM **PLATHELMINTHES** - 31–130
  CLASS **TREMATODA** - 31–87
Definition—Morphology—Development - 31–36
  Family dicrocœliidæ: **Dicrocœlium—Platynosomum—Eurytrema** 37–41
  Family opistorchiidæ: **Opistorchis—Pseudamphistomum** - 41–45

PAGES

Family FASCIOLIDÆ: **Fasciola—Fascioloides—Fasciolopsis** 45–54

Family ECHINOSTOMATIDÆ: **Echinostoma—Echinoparyphium—Hypoderæum—Echinochasmus—Euparyphium** 54–59

Family HETEROPHYIDÆ: **Heterophyes—Metagonimus—Euryhelmis** 59–62

Family PLAGIORCHIDÆ: **Prosthogonimus** 62–65

Family NOTOCOTYLIDÆ: **Notocotylus—Catatropis—Cymbiforma** 65–66

Family BRACHYLÆMIDÆ: **Brachylæmus** 66

Family TROGLOTREMATIDÆ: **Paragonimus—Collyriclum—Troglotrema** 67–72

Family CYCLOCŒLIDÆ: **Typhlocœlum—Hyptiasmus** 72–73

Family PARAMPHISTOMIDÆ: **Paramphistomum—Cotylophoron—Gastrothylax—Fischœderius—Carmyerius—Gastrodiscus** 73–78

Family STRIGEIDÆ: **Apatemon—Parastrigea—Cotylurus** 78–80

Family SCHISTOSOMATIDÆ: **Schistosoma—Ornithobilharzia—Bilharziella** 80–87

CLASS CESTODA 87–130

DEFINITION—MORPHOLOGY—DEVELOPMENT 87–91

Family DIPHYLLOBOTHRIIDÆ: **Diphyllobothrium—Sparganum** 91–94

Order CYCLOPHYLLIDEA 94–130

Family MESOCESTOIDIDÆ: **Mesocestoides—Dithyridium** 94–95

Family ANOPLOCEPHALIDÆ: **Anoplocephala—Paranoplocephala—Moniezia—Cittotænia—Avitellina—Stilesia—Thysanosoma—Thysaniezia** 95–102

Family DAVAINEIDÆ: **Davainea—Raillietina—Cotugnia—Houttuynia** 102–106

Family DILEPIDIDÆ: **Amœbotænia—Choanotænia.** Tæniasis in poultry. **Dipylidium.** Tæniasis in dogs and cats. **Joyeuxiella—Diplopylidium Metroliasthes** 106–112

Family HYMENOLEPIDIDÆ: **Hymenolepis—Fimbriaria** 112–114

Family TÆNIIDÆ: **Tænia—Echinococcus** 114–130

PHYLUM NEMATHELMINTHES 130–271

CLASS NEMATODA 130–266

DEFINITION—MORPHOLOGY—DEVELOPMENT—CLASSIFICATION 130–135

Order ASCAROIDEA 135–155

Family ASCARIDÆ: **Ascaris—Toxascaris—Toxocara.** Ascariasis in dogs, cats and fur-bearing animals. **Aniskinæ: Porrocæcum** 136–145

Family HETERAKIDÆ: **Heterakis—Ascaridia—Subulura** 145–150

Family KATHLANIIDÆ: **Probstmayria** 150

Family OXYURIIDÆ: **Oxyuris—Passalurus—Skrjabinema** 150–152

Family RHABDITIDÆ: **Rhabditis—Strongyloides** 152–155

Order TRICHINELLOIDEA 155–163

Family TRICHINELLIDÆ: **Trichinella—Trichuris—Capillaria** 156–163

PAGES

Order STRONGYLOIDEA - - - - - - - 163–233

Family STRONGYLIDÆ: **Strongylus.** Life-cycle and bionomics of strongyle larvæ. **Triodontophorus—Œsophagodontus—Craterostomum—Gyalocephalus—Poteriostomum—Trichonema.** Equine strongylidosis. **Codiostomum—Bourgelatia—Œsophagostomum.** Prophylaxis against nematode parasites of ruminants. **Chabertia—Stephanurus—Syngamus—Cyathostoma** - - - 164–190

Family ANCYLOSTOMIDÆ: **Ancylostoma—Uncinaria.** Ancylostomiasis and uncinariasis in dogs, cats and foxes. Creeping eruption. **Agriostomum—Necator—Bunostomum—Gaigeria—Globocephalus** 190–201

Family AMIDOSTOMIDÆ: **Amidostomum** - - - - - 201–202

Family TRICHOSTRONGYLIDÆ: **Trichostrongylus—Graphidium—Hyostrongylus—Ornithostrongylus—Libyostrongylus—Ostertagia—Marshallagia—Cooperia—Nematodirus—Hæmonchus—Mecistocirrus—Ollulanus** - - - - - - - - - 202–220

Family METASTRONGYLIDÆ: **Dictyocaulus — Metastrongylus — Protostrongylus — Neostrongylus — Muellerius — Æurostrongylus—Angiostrongylus—Filaroides—Crenosoma** - - - 220–233

Order SPIRUROIDEA - - - - - - - 233–254

Family SPIRURIDÆ: **Habronema—Hartertia—Spirocerca** - - 233–240

Family ASCAROPIDÆ: **Ascarops—Physocephalus—Simondsia—Gongylonema** - - - - - - - - 240–244

Family ACUARIIDÆ: **Acuaria—Tetrameres** - - - - 244–248

Family PHYSALOPTERIDÆ: **Physaloptera** - - - - 248–250

Family THELAZIIDÆ: **Thelazia—Oxyspirura** - - 250–252

Family GNATHOSTOMIDÆ: **Gnathostoma** - - - - 252–254

Order FILAROIDEA - - - - - - - 254–264

Family FILARIIDÆ: **Dirofilaria—Acanthocheilonema—Parafilaria—Onchocerca—Elæophora—Setaria—Suifilaria—Stephanofilaria** 255–263

Family DRACUNCULIDÆ: **Dracunculus** - - - - - - 263–264

Order DIOCTOPHYMOIDEA - - - - - - - 264–266

Family DIOCTOPHYMIDÆ: **Dioctophyma—Hystrichis** - - 264–266

CLASS NEMATOMORPHA - - - - - - - - 266

Mermithida AND **Gordiacea** - - - - - - - - 266

CLASS ACANTHOCEPHALA - - - - - 266–271

MORPHOLOGY—DEVELOPMENT - - - - - - 266–267

Family ECHINORHYNCHIDÆ: **Polymorphus—Filicollis** - - 267–269

Family GIGANTORHYNCHIDÆ: **Macracanthorhynchus—Oncicola** - 269–271

PHYLUM ANNELIDA - - - - - - - 272–274

CLASS HIRUDINACEA - - - - - - 272–274

MORPHOLOGY - - - - - - - - - 272

Hirudo—Limnatis—Hæmadipsa - - - - - 272–274

SECTION IV

ARTHROPOD PARASITES

PAGES

PHYLUM **ARTHROPODA** - - - - - - - - 275-404

CLASSIFICATION—MORPHOLOGY—DEVELOPMENT - - - - - 275-292

A. DIRECTLY POISONOUS ARTHROPODA - - - - 292

Myriapoda—Insecta: Piercing or biting forms; stinging insects; nettling forms; cryptotoxic forms. Scorpions. **Solpugida—Araneida—Acarida:** Mites in foodstuffs - - - - - - - 292-297

B. ARTHROPODA AS PARASITES AND TRANSMITTERS OF DISEASE - - - - - - - - - 297

CLASS **INSECTA** - - - - - - - - - 297
Order ORTHOPTERA - - - - - - - - - 297
COCKROACHES - - - - - - - - - 297
Order COLEOPTERA - - - - - - - - - 298
Order DIPTERA - - - - - - - - - 298-348
Sub-Order **Orthorrhapha** - - - - - - 298-307
Family CHIRONOMIDÆ: **Culicoides—Ceratopogon** - - - - 299
Family SIMULIIDÆ: **Simulium** - - - - - - 299-301
Family PSYCHODIDÆ: **Phlebotomus** - - - - - - - 301
Family CULICIDÆ: **Culex—Aedes—Anopheles** - - - 301-305
Family TABANIDÆ: **Tabanus—Hæmatopota—Chrysops—Pangonia** 305-307
Sub-Order **Cyclorrhapha** - - - - - - - 307-344
Family SARCOPHAGIDÆ: **Sarcophaga—Wohlfahrtia** - - 307-308
Family ŒSTRIDÆ: **Gastrophilus — Œstrus — Hypoderma — Dermatobia** - - - - - - - - - 308-316
Family MUSCIDÆ - - - - - - - - - 316
Sub-Family **Muscinæ: Musca** - - - - - - 317-320
Sub-Family **Calliphorinæ: Lucilia—Calliphora—Microcalliphora—Chrysomyia—Cochliomyia.** Calliphorine myiasis in sheep. Screw-worms in cattle and other animals. **Cordylobia—Booponus** 321-333
Sub-Family **Stomoxinæ: Stomoxys—Lyperosia** - - 333-336
Sub-Family **Glossininæ: Glossina** - - - - - 336-344
APPENDIX: Pupipara - - - - - - - - - 344
Family HIPPOBOSCIDÆ: **Hippobosca—Melophagus—Pseudolynchia** 344-348
Order HEMIPTERA - - - - - - - - 348-349
Cimex—Ornithocoris - - - - - - - 348-349
Order ANOPLURA - - - - - - - - 349-356
Sub-Order **Mallophaga** - - - - - - - - 350-353
Menopon—Eomenacanthus—Lipeurus—Goniocotes—Goniodes—Columbicola—Bovicola—Trichodectes—Heterodoxus—Felicola. Pediculosis in poultry - - - - - - 350-353

PAGES

Sub-Order **Siphunculata** 353–356

Hæmatopinus—Linognathus—Solenopotes. Pediculosis in domesticated mammals 353–356

Order SIPHONAPTERA 356–358

Ctenocephalides—Ceratophyllus—Pulex—Echidnophaga 356–358

CLASS **ARACHNIDA** 358–403

Order ACARIDA 358–403

Super-Family **Ixodoidea** 358–381

Family ARGASIDÆ: **Argas—Otobius—Ornithodoros** 358–362

Family IXODIDÆ: **Ixodes.** Tick paralysis. **Boophilus—Margaropus—Hyalomma—Rhipicephalus—Hæmaphysalis—Dermacentor—Rhipicentor—Amblyomma—Aponomma.** Ticks as parasites 363–381

Super-Family **Sarcoptoidea** 382–397

Family SARCOPTIDÆ: **Sarcoptes — Cnemidocoptes — Notœdres — Psoroptes—Chorioptes—Otodectes** 382–396

Family CYTOLEICHIDÆ: **Cytoleichus—Laminosioptes** 396–397

Super-Family **Parasitoidea** 397–399

Family DERMANYSSIDÆ: **Dermanyssus—Liponyssus—Pneumonyssus** 397–399

Family CHEYLETIDÆ: **Psorergates** 399

Super-Family **Trombidoidea** 400

Family TROMBIDIIDÆ: **Trombicula—Neoschongastia** 400

Super-Family **Tarsonemoidea** 401

Family PEDICULOIDIDÆ: **Pediculoides** 401

Super-Family **Demodicoidea** 401–403

Family DEMODICIDÆ: **Demodex** 401–403

CLASS **PENTASTOMIDA** 403–404

Family PORCEPHALIDÆ: **Linguatula—Porocephalus** 403–404

HOST PARASITE LIST 405

ALPHABETICAL INDEX 415

INTRODUCTION

THE gradually increasing realisation of the importance of parasitic diseases has stimulated research in this subject particularly during the last few decades, and much information has been accumulated. Although the more intricate problems like metazoan immunity and the physiology of parasites are beginning to receive a fair amount of attention, the descriptive nature of the work has predominated in the past, and a vast number of parasitic helminths and arthropods are now known. One therefore realises that the definite determination of a parasite is frequently a difficult matter, requiring a good deal of training and knowledge of the literature. But although a specific diagnosis of most parasitic diseases can be made only by the identification of the causal agent, this is not too great a problem in the case of parasitic diseases of the domesticated animals.

While the morphological descriptions given in this volume have been curtailed to the extreme, an attempt has been made to point out just those characteristics by which the parasites can be recognised, knowing the host and the organ in which they occur, and to supplement these descriptions by specially selected illustrations of parasites, plates of those eggs which can be recognised in the fresh fæces and descriptions of larval forms, all of which are important for the purpose of diagnosis.

In the case of many *Diptera*, such as the species of blowflies and *Glossina*, and also the ticks, specific descriptions are not given, since these would have increased the bulk and the price of the book considerably, and would also have necessitated the consideration of morphological details, like chætotaxy, which do not lie within the scope of the book. The student who requires further information on morphological matters or on parasites not mentioned in this book is referred to the textbooks and other literature mentioned on the next page and in the text. References to literature on special topics are given in the form of footnotes, and the reader will find further important details in the papers mentioned.

The host animals considered are the following: Birds—fowl (*Gallus gallus*), turkey (*Meleagris gallopavo*), pigeon (*Columba livia domestica*), guinea-fowl (*Numida meleagris*), pea-fowl (*Pavo cristatus*), duck (*Anas boschas domestica*), goose (*Anser anser domesticus*), swan (*gnus Cyolor* *domesticus*), ostrich (*Struthio* spp.). Mammals—horse (*Equus caballus*), donkey (*Equus asinus*), mule (*Equus asinus* × *Equus caballus*), sheep (*Ovis aries*), goat (*Capra hircus*), cattle (*Bos taurus*), pig (*Sus scrofa domestica*), dog (*Canis familiaris*), cat (*Felis domestica*), fox (*Vulpes vulpes*), badger (*Meles meles*), otter (*Lutra lutra*), beech marten (*Martes foina*), pine marten (*Martes martes*), mink (*Lutreola vison*), polecat (*Putorius putorius*), stoat (*Mustela erminea*), weasel (*Mustela nivalis*), skunk (*Mephitis mephitis*), raccoon (*Procyon lotor*), rabbit (*Oryctolagus cuniculus*), beaver (*Castor fiber*), coypu (*Myocaster coypus*), muskrat (*Ondatra zibethica*), squirrel (*Sciurus vulgaris*), hamster (*Circetus circetus*).

With regard to the names of parasites used, these are believed to be correct according to the rules of the International Commission on Zoological Nomenclature. Well-known synonyms have been added for the guidance of readers who may know the parasites under these names only. It has been taken for granted that the student has been taught the ordinary rules of nomenclature and methods of classification during his preliminary course in zoology and botany, hence no reference is made to these matters.

TEXTBOOKS FOR FURTHER INFORMATION.

BAYLIS: A Manual of Helminthology, Medical and Veterinary. Baillière, Tindall and Cox, London, 1929.

MARTINI: Lehrbuch der Medizinischen Entomologie. G. Fischer, Jena, 1923.

PATTON AND EVANS: Insects, Ticks, Mites and Venomous Animals of Medical and Veterinary Importance. Three volumes. Liverpool School of Tropical Medicine.

RILEY AND JOHANNSEN: Handbook of Medical Entomology. Comstock Publishing Company, Ithaca, New York, 1915.

SPREHN: Lehrbuch der Helminthologie. Gebr. Bornträger, Berlin, 1933.

YORK AND MAPLESTONE: The Nematode Parasites of Vertebrates. J. and A. Churchill, London, 1926.

VETERINARY HELMINTHOLOGY AND ENTOMOLOGY

SECTION I

GENERAL

PARASITOLOGY is that part of biology which deals with organisms that live in or on other organisms, called their hosts. The parasite benefits by this association, while the host suffers.

Since human and veterinary medicine is an applied biological science, parasitology finds its most important application in this field, especially in tropical medicine. The student of tropical medicine as well as the parasitologist, therefore, requires a good deal of general and special biological training in order to understand the tropical parasitic diseases, especially if he desires to promote the knowledge of their control.

A study of the morphological characteristics of parasites, which the student may consider to be an unnecessary extension of his difficult task, is nevertheless an exceedingly important part of the subject, since it is indispensable for the diagnosis of every parasitic disease. Parasites which look much alike may differ greatly in their pathogenicity and habits and require quite different measures for their control. Alternatively, very similar symptoms may be produced by parasites of very different nature, so that the symptoms frequently do not give an indication as to the nature of the parasite and the preventive measures that have to be instituted. The diagnosis of a parasitic disease has always to be confirmed by the identification of the parasite itself or its eggs or larvæ obtained from the diseased host.

This, however, is only a part of the knowledge required by the medical parasitologist. More important is the knowledge of the pathogenicity of the parasite, the pathogenesis and the symptoms of the disease caused by it, and the most expedient methods of treatment and prevention. Prevention of infection by extermination of the parasite, especially its pre-infective stages, or of its intermediate host, should always be the main object. Treatment of infected animals should be considered mainly as a measure for the prevention of further spread of the infection and never as the only and final measure. For this reason the most important part of parasitology is an intimate knowledge of the life-histories and habits of parasites in the widest sense, because on this knowledge measures of prevention and eradication are based.

The importance of parasitology in warm climates cannot easily be overestimated. The most common and destructive diseases of animals in tropical and subtropical countries are caused or transmitted by parasites. In temperate climates the importance of parasitic diseases is frequently underestimated. An important fact that needs to be more generally stressed is that the effects of parasitic diseases are often not as spectacular as those of infectious diseases, which frequently appear in the form of epizootics. It is the slowly gnawing danger of the parasite that is not realised, and the susceptibility to other diseases which it produces. A flock of sheep, for instance, though suffering from worm infection, may be quite passable in appearance, and the owner as well as the veterinarian may become accustomed to this condition, considering it the normal for sheep in that area. But these sheep would really be in a much better condition if they had no parasites. If one could calculate the loss in quantity and quality of wool, loss due to slower growth, weak and undernourished lambs, etc., one would realise that this constant slight drain on the animals by the parasites is well worth the attention of those concerned. It should, therefore, be the aim of the parasitologist to exterminate all parasites.

1. PARASITISM AND OTHER FORMS OF LIFE

Almost all the phyla of the animal kingdom contain parasitic forms. The Echinodermata apparently contain none, while the Porifera, the Cœlenterata, the Mollusca and the Vertebrata contain very few. The most important parasites are found amongst the Protozoa, the Plathelminthes, the Nemathelminthes and the Arthropoda. The Mollusca and the Arthropoda provide many important intermediate hosts.

Parasitic life does not stand apart from other forms of existence, since parasites have originated from free-living organisms, and many intermediate forms occur. Certain species of flies which used to breed in carcasses, later adopted the habit of laying their maggots or eggs in wounds. Such maggots would be termed parasites, while another batch laid by the same fly in a carcase would not fall into this category. Similarly, the differences between parasites and herbivorous or carnivorous animals is one of degree only. The herbivore or carnivore is usually larger and stronger than its prey and takes large bites, while the parasite is smaller than its host and takes small bites.

Any form of existence in which two different species of organisms live in close approximation is called *Symbiosis.* The term is frequently used in a restricted sense for an association which is of mutual benefit and at the same time obligatory. When mutual benefit is derived from such cohabitation one speaks of *Mutualism.* As an example may be quoted the hermit crab, which lives in the shell of a mollusc, while a sea-anemone grows on the shell. The crab is to some extent protected from its enemies, while the anemone is carried about and thus obtains more food than its sessile habits would otherwise allow. A more striking example is afforded by the flagellates, which live in the intestines of termites. Cleveland has shown that the flagellates act on the cellulose of the wood eaten by the termites, rendering it digestible for the latter, and that without the flagellates the termites would starve to death. The flagellates at the same time are afforded food and protection.

When one party alone benefits but the other does not suffer, one speaks of *Commensalism.* Many bird-lice, for instance, feed on epidermal debris and do very little harm to their hosts.

When one party benefits and the other suffers, the condition is called *Parasitism.* It is obvious that the parasite can have no intention of doing harm to the host and that this would not even be in the interest of the parasite itself. The damage is done accidentally, especially if the number of the parasites becomes too large. To speak of non-pathogenic parasites is, therefore, not correct; they should be called commensals, but it is frequently not an easy matter to determine whether harm is done or not.

When a parasite spends different parts of its life-cycle in two or more hosts, one of these is called the final or definitive host and the other the intermediate host. There may be two intermediate hosts: a primary and a secondary. In the case of helminths, the final host is that one in which the adult or sexually reproducing stage of the parasite lives, while the intermediate host harbours larval or asexually reproducing forms. The adoption of the intermediate host is undoubtedly a secondary development, necessitated by the advanced adaptation of the parasite to a parasitic existence, thus losing the ability to live free for a part of its life. On the other hand, we find among the Arthropoda parasitic larval stages, while the adults live free (myiasis-producing forms).

2. TYPES OF PARASITIC RELATIONS

Parasites may be grouped as:

1. *Ectoparasites*—living on the host; and

Endoparasites—living within the body of the host. The distinction is not always clear; for instance, *Sarcoptes* burrows in the skin, but is called an ectoparasite. In general, arthropod parasites are called ectoparasites and helminths endoparasites.

2. *Obligatory*—completely adapted to a parasitic mode of life, *e.g.* filarial worms, cestodes, etc.; and

Facultative—able to exist free or as parasites, *e.g.* Calliphorine maggots.

3. *Permanent*—always living as parasites, *e.g.* lice, tapeworms;

Temporary—living free during a part of the life-cycle, *e.g. Gastrophilus*, *Hæmonchus*; and

Periodic—attacking the host for short periods to obtain food, *e.g.* mosquitoes.

4. *Erratic*—occurring in an organ which is not their normal habitat, *e.g. Fasciola hepatica* in the lungs.

5. *Incidental*—occurring in an animal which is not their normal host, *e.g. Ascaris lumbricoides* in sheep.

3. PATHOGENICITY AND PATHOGENIC EFFECTS

The pathogenicity of parasites varies greatly, depending on their numbers, their habits, whether migration takes place in the host, and especially the degree of adaptation that has developed between the host and the parasite. When multiplication occurs in or on the host, as in the case of lice, scab and mange mites and many protozoa, the increase in numbers is an important factor. It should be borne in mind that a few parasites usually do not affect the health of the host, and in almost all instances there is a certain " threshold value " or number of parasites that can be harboured without ill effects.

Parasites may do harm to their hosts in the following ways:

1. By absorbing food intended for the host, *e.g.* tapeworms.
2. By sucking blood or lymph, *e.g.* hookworms, ticks.
3. By feeding on the tissues of the host, *e.g.* ascarids, maggots.
4. By causing mechanical obstruction or pressure, *e.g.* ascarids, microfilariæ, multiceps.
5. By causing the growth of nodules and tumours and by perforating vessels, *e.g. Œsophagostomum*, *Habronema megastoma*, *Spirocerca lupi*. In certain cases such tumours may be of a malignant nature, *e.g.* those produced by *Gongylonema neoplasticum* in rats, *Cysticercus fasciolaris* in rats, *Heterakis isolonche* in pheasants and *Opistorchis felineus* in cats and man. The parasite, however, is probably not in itself the only cause of such a tumour, and only stimulates its development in a body which is susceptible on account of the presence or absence of an unknown primary factor.
6. By causing wounds through which infection may enter, *e.g.*

Ascaris, *Demodex*, or by reducing the resistance of the host to other infections, *e.g.* lungworms.

7. By destruction of tissues, *e.g.* *Cysticercus tenuicollis*, *Dioctophyma renale*.

8. By irritation, *e.g.* lice, *Œstrus ovis*, *Simulium*, *Fasciola*.

9. By secreting toxins or otherwise harmful substances, such as:

   (*a*) Antidigestive enzymes, *e.g.* gastro-intestinal worms.
   (*b*) Digestive enzymes, *e.g.* Trichonemas, maggots of blowflies.
   (*c*) Anticoagulatory and hæmolytic enzymes, *e.g.* hookworms, blood-sucking Arthropoda.
   (*d*) Other secretions, excretions and body fluids, *e.g.* *Diphyllobothrium*, ascarids, *Gastrophilus*.

10. By transmitting the causal agents of infectious diseases, such as bacteria, rickettsias, ultravisible viruses, blood protozoa, spirochætes and filariæ.

Worm parasites frequently cause a marked eosinophilia. This is often seen when the host has developed a certain degree of resistance to the parasite or its effects.

Diseases caused by worms are generally known as verminoses or helminthiases. Diseases caused by single species or groups of parasites are usually called after the ætiological agent, *e.g.* fascioliasis caused by *Fasciola*, hæmonchosis caused by *Hæmonchus*, pediculosis caused by *Pediculus* or other lice, tæniasis caused by *Tænia* or other tapeworms. Sometimes other names are used, *e.g.* myiasis caused by dipterous larvæ.

4. HOST AND ORGAN SPECIFICITY

In general, any species of parasite associates only with particular species of hosts or only a single species. If a parasite has more than one host species these hosts are usually closely related. There are very few parasites that can live in a large range of hosts, for instance *Trichinella spiralis*, *Sarcoptes scabiei*. Some parasites of cattle are not able to live in sheep, and even some that occur in the donkey are not found in the horse. On the other hand, wild animals have been found to harbour many parasites that can establish themselves in related domestic animals, and this fact should be borne in mind in connection with control measures.

The host is said to be *tolerant* or *refractory* to a certain parasite depending on whether the parasite is or is not able to establish itself in the host. An animal is said to be the *natural host* of a parasite when the latter is able to develop and live normally in it. For instance, 92 per cent. of *Echino-*

coccus granulosus cysts in sheep are fertile, but in cattle only 10 per cent.; sheep would therefore be more natural hosts than cattle.

If a parasite enters an unsuitable host it either dies very soon or it may develop for a time, but does not reach sexual maturity, or, in certain cases, it may become encysted and be able to complete its development if it should eventually find its way into a suitable host, *e.g. Physocephalus sexalatus, Spirocerca lupi.*

Each species of parasite has its predilection site in or on the host. The reasons underlying this organ specificity are not clear, although in some cases the site is the most obvious one, as in the case of tapeworms, which, possessing no alimentary canal, and therefore having to absorb digested food material, obviously find the best conditions in the alimentary canal of the host; only a few species of tapeworms are found elsewhere.

All organs of the body are subject to parasitic attack. Of the internal parasites, the largest number inhabit the alimentary canal, especially the intestine. The lungs, body cavities and bloodvessels are also frequently the seats of parasites, and even the heart, brain, eye and bones do not escape.

Incidental parasites are often erratic, especially when their young stages have to migrate through the body of the host, *e.g. Fasciola hepatica* may occur in man under the skin and in horses in the lungs. Chandler suggests that the parasite goes astray because it misses the guiding stimuli (which are probably of a chemotactic nature) by which it is led in its normal host. Occasionally parasites are erratic even in their normal hosts—for instance, *Strongylus edentatus* in the horse and *Stephanurus dentatus* in the pig—and they are therefore apparently not as sensitive to the guiding stimuli as others are. Erratic parasites may at times produce serious disturbances, of which the cause is often difficult to determine.

5. RESISTANCE AND IMMUNITY

Resistance or immunity to metazoan parasites occurs and is comparable to immunity to bacterial infections, but it is not always as marked. A differentiation can be made between resistance to parasitic invasion and resistance to the effects of a parasitic infection, although both depend mainly on the degree of adaptation between the host and the parasite. It is well known that adaptation can lead right to the state of commensalism, in which the host suffers no ill effects, while in the case of a comparatively recent and hence unadapted combination the greatest incompatibility is observed. This is well illustrated by *Syngamus trachea*, which is practically non-pathogenic to turkeys and to which turkeys are tolerant at all ages, while it is very pathogenic to fowls, and these hosts develop a strong refractoriness to it at an early age.

Resistance to the effects of parasites is also influenced by secondary factors such as nutrition, age and all factors that affect the general condition of the host.

Natural immunity to invasion by different species of parasites varies from an absolute refractoriness to complete tolerance or a total absence of immunity. The intervening grades of resistance depend on the stage of adaptation, and here it is usually observed that mature animals are less susceptible than young animals. This *age immunity* is really identical with natural immunity, since it forms a part of the physiological characteristics of the host species, which are fully developed only in the mature animal, as has been pointed out by Looss.

Specificity as discussed in the preceding section is therefore not absolute. Experimentally parasites have been adapted to new hosts and *vice versa.* Natural immunity is also markedly influenced by nutrition, vitamins and general condition. The practical importance of these facts cannot easily be overstressed; good feeding is one of the best prophylactic measures against parasites.

Acquired Immunity.—As a rule repeated infections do not have a cumulative effect above a certain limit. In some cases a strong immunity results from one infection so that reinfection is unsuccessful. In other cases of continued reinfection the effect on the parasites may be stunting of growth or complete inhibition of development beyond a certain stage, or decreased egg-output or all of these. Whether such immunity is of a local nature or due to immune bodies in the blood of the host has been determined in very few cases. A definite local immunity of the affected area and its immediate surroundings develops in the skin of animals infected with the maggots of *Cordylobia anthropophaga.* On the other hand, several investigators have been able to immunise animals against worm infection by the injection of ground worm material of the same species, or have transferred immunity from hyperimmunised animals to others by means of injected blood serum. Immunity may also be transmitted from mother to young in certain cases. Trager found that a similar general immunity develops in guinea-pigs against the tick *Dermacentor variabilis.*

Acquired immunity is usually quite specific, but Chandler has produced a certain degree of resistance in rats to the nematode *Nippostrongylus muris* by injecting larvæ of the related *Longistriata.*

Apart from immune bodies the host may also develop an allergic condition, which is, however, less specific and is used for diagnostic purposes (p. 28).

6. EFFECT OF PARASITIC LIFE ON THE PARASITE

Parasitism is not a degradation but a specialisation. In accordance with their mode of life parasites have undergone great morphological changes with the loss of unnecessary organs and the development of others. How such an adaptation to parasitic life comes about cannot be discussed here; it is, in fact, a rather dark problem. Very striking is the loss of certain sense organs, like eye-spots in internal parasites, the loss of wings in certain external parasites, and even the alimentary canal in tapeworms and *Acanthocephala*. Special development is seen in organs of adhesion such as hooks and suckers of worms and claws of lice, as well as in the organs of reproduction, particularly in the case of internal parasites. The latter cannot lay their eggs or larvæ in suitable places, but must leave them to chance, and would soon become extinct if they did not produce enormous numbers of offspring. Some hookworm females lay each 10,000 eggs per day, while *Ascaris lumbricoides* lays as many as 250,000.

A result of this increased reproductive activity is frequently a marked sexual dimorphism, the females being much larger or occurring in greater numbers than the males, as, for instance, among the *Oxyuridæ*.

Adaptation to parasitic life complicates the life-cycle of the organism, often necessitating the acquisition of an intermediate host for shelter (primarily) and for development and transmission (secondarily) of those stages that live outside the body of the definitive host. Some of the intermediate stages become highly specialised, mainly in order to increase the chances of perpetuating the race by further multiplication; for instance: sporocyst, echinococcus.

The metabolism of internal parasites is also greatly altered, especially that of the gastro-intestinal worms. This subject is of great importance in connection with the investigation of anthelmintics, but little is yet known about it. The researches of Weinland, Von Brand* and others have shown that worms like *Fasciola hepatica* and intestinal worms live anaerobically and obtain their energy by converting glycogen into carbon dioxide, fatty acids and even fats, which are excreted. They may, however, also be able to make use of the small quantities of oxygen in their surroundings.

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* *Ergebn. d. Biol.*, 10: 37-100. 1934.

7. EPIZOOTOLOGY

The factors that can be considered under this heading are many in number and of the utmost importance in practice. They will be dealt with in the following chapters in greater detail, but a few general points will be summarised here.

The epizootology of a parasitic disease may be divided into three sections as follows:

1. Dissemination of the infection by the host and other agencies. It should be realised that animals live under very unhygienic conditions as compared to man, since their fæces and urine are voided on the pastures on which they feed and in the stables in which they live. The infective material can be spread further by wind, water and numerous animals like dung-beetles, flies, earthworms, pigs and birds.

2. The fate of the infective material, its development in the free state or in intermediate hosts, and its further distribution by the latter or by mechanical carriers. Climatic factors like temperature, rainfall (total amount and seasonal distribution) and sunshine, as well as altitude, topography, type of soil and type of vegetation, all have an important bearing on this aspect of the epizootology.

3. The factors that lead to the infection of new hosts.

Infection is acquired in the following ways:

(i.) By contagion—that is, direct contact. This is relatively rare, *e.g.* scab, lice, keds.

(ii.) Through food or water, *e.g.* the eggs or larvæ of many worms or the infected intermediate hosts.

(iii.) Through inoculation by intermediate hosts, *e.g.* filarial worms.

(iv.) Through direct attack by the parasites, *e.g.* hookworms, schistosomes, blowflies, bots, ticks.

(v.) Through hereditary transmission. The best examples in this category are found among the protozoan parasites, *e.g.* spirochætes in *Argas* and *Babesia bigeminum* in *Boophilus*. Among the metazoan parasites prenatal infection is sometimes of great importance, *e.g.* ascarids in puppies.

The habits of the hosts also form an important factor. Swine, on account of their scavenging habits, are more liable to become infected with tapeworm eggs from human fæces than are cattle—not considering for the moment the fact that the parasites are different in the two cases. Again calves, on account of their habit of licking all kinds of objects, become more easily infected than adult cattle. And the latter again, because they graze high, will pick up nematode larvæ less readily than sheep that graze close to the ground.

8. GEOGRAPHICAL DISTRIBUTION

A parasite cannot exist where there is no suitable host or intermediate host. It is an interesting fact that in different countries a parasite may acquire different intermediate hosts, but in some cases the intermediate host may not be very suitable and, while all other factors appear to be equal, the incidence of the disease remains low. Cases are known in which a parasite has a principal intermediate host and some others that are less suitable—for instance, East Coast fever transmitted by *Rhipicephalus appendiculatus* and also by other species of *Rhipicephalus*—and the parasite does not flourish where the principal intermediate host is absent.

The host specificity of parasites allows some very interesting conclusions to be drawn with regard to the relations and geographical distribution of the hosts. In general, it is accepted that, if two species of hosts harbour the same or two closely related species of parasites, the hosts are descended from the same ancestral stock which harboured the ancestral parasite and are, therefore, fairly closely related. This must be taken with some reservation, since parasites sometimes acquire new hosts; for instance, *Fasciola hepatica*, which is normally a ruminant parasite, is also found in rabbits and in kangaroos in Australia. However, there are many fairly clear cases, *e.g.* closely related worms of the genus *Dicheilonema* occur in the South American rhea and the South African ostrich, providing evidence, in addition to the morphological similarity of the birds, that they are closely related and that there was formerly a land connection between these two countries.

Some parasites, such as lice and tapeworms of birds, are considered to be so specific that they could be used to indicate relationships in connection with the classification of their hosts.

9. HISTORICAL

A short summary of the development of parasitology, especially with reference to the earlier helminthological work, may be useful to indicate that exact observations are more valuable than theories, especially when they seem to contradict all past experience, and that it is not in the interest of progress to be dogmatic.

Parasites were known and discussed many centuries ago, for instance by Aristotle and Hippocrates, but it is really only during the last few decades that the subject has made great strides, on account of the increasing realisation of its importance and the amount of exact knowledge that has been gained.

The occurrence of parasites in living animals, especially in the internal organs, provided an opportunity for propounding the most fantastic theories with respect to their origin. While the idea of spontaneous generation held the field, and fleas, etc., were thought to arise out of dust and dirt, it was not difficult to conceive that parasites could be formed by the pathological processes taking place in a diseased organ. The theory of spontaneous generation explained the origin of all lower animals whose development was not known, like that of mammals and birds, and they were generally thought to arise from inanimate matter. The internal parasites were considered to provide a very strong argument in favour of this idea, and any discussion that did take place with regard to their origin centred round the question of what was the actual material from which they were formed—blood, undigested food, secretions, etc.—and the initial causes of their formation—fermentation, decomposition or a special organising principle or humour.

In 1712 Redi showed that maggots found in decomposing meat were young stages of flies, and in 1752 Swammerdam showed that lice developed from eggs. This was great progress, but the old dogmas were very strong, and neither of these workers had the courage to disclaim them.

With the advent of the microscope, however, a new era of progress appeared to begin. Numerous small organisms were found to exist in water, food and soil, and they were thought to be the precursors of parasites, as they could easily be swallowed. Many parasites were then found to be sexually reproducing organisms that laid eggs, and the idea was advanced that the eggs entered the bloodstream and that parasites were thus inherited by the offspring of the host, while those eggs that passed out of the body, *e.g.* with the fæces, were lost. Pallas first declared that parasites develop from eggs and that the latter were the means of spreading the infection, but this suggestion fell on unfertile ground; and we find the remarkable fact that the ideas reverted again to the old theory of spontaneous generation, perhaps because this was, after all, the simplest and it enjoyed the authority of long standing.

The great and final break came eventually with the discovery of Mehlis in 1831, that larvæ hatched from the eggs of Trematodes, followed by more similar discoveries, of which a very important one was that of Küchenmeister in 1852, who showed that the pig measle (*Cysticercus cellulosæ*) was the intermediate stage of the human tapeworm, *Tænia solium*. Even then a large amount of opposition was encountered; for instance, Von Siebold maintained that the cysticerci were tapeworms with hydropically degenerate bodies, which was due to the fact that they had developed in an abnormal host, and that they were not necessary intermediate stages.

Much of the older work is practically valueless today and the cause of great trouble, on account of its inexact nature. As a science advances the degree of detail required increases because more and more difficulties are realised, and our observations of today may be quite insufficient in the next century; but if they are at least exact they will always be valuable. This can be seen from the value that is still attached to the work of men like Leuckart, who were exact observers and truthful recorders, although they did not always recognise the significance of their observations.

SECTION II

TECHNIQUE

COLLECTION AND PRESERVATION OF HELMINTHS

THE collection of parasites from an animal should be carried out as systematically and completely as possible. For this purpose it is wise to follow a definite scheme and examine each organ as is done at an autopsy, beginning with the outside of the body, then the subcutaneous tissues, the body cavities and so forth.

Filariid worms found under the skin and in the body cavities and bloodvessels are very liable to burst and are best placed immediately into a 10 per cent. solution of formalin, without washing in saline, unless they are soiled with blood.

Large nematodes should be collected and washed by shaking in 0·9 per cent. saline and immediately dropped into boiling 70 per cent. alcohol, which causes them to be fixed in an extended state. They can be stored in the fixative, but, where there is danger of evaporation, 5 per cent. glycerin should be added.

Nematode larvæ or small adult nematodes situated in tissues are difficult to extirpate, but will often leave the tissues if these are placed into a dish of warm physiological saline. The dish should be watched, and the worms removed and fixed as soon as they are free.

Cestodes must be collected with the heads, as these are of great importance for identification. The worms are placed into a dish of warm water at about 40° C., and if their heads are attached to the intestinal wall, a piece of the latter is cut out and also placed in the dish. The worms will die fully extended usually in about an hour, and the heads will be free or may have to be dissected out. The worms are fixed, for permanent preparations, in cold 70 per cent. alcohol with 5 per cent. glycerin, or equal parts of 70 per cent. alcohol, glycerin and distilled water, or Zenker's fluid, drawing large forms a few times over the hand or the edge of the vessel and small ones rapidly through the fluid, in order to get them fully extended. When fixing in Zenker's fluid the worms must be removed after 24 hours and thoroughly washed in running water.

For immediate identification of cestodes Meggit* recommends placing

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* *Parasitology*, 16 (3): 266-268. 1924.

the live heads and terminal gravid segments into lactophenol (1 part lactic acid, 1 part carbolic acid, 2 parts glycerin and 1 part water) on a slide and covering with a coverslip. The mature segments can be stained alive in a freshly made mixture of 97 parts of a saturated solution of carmine in 45 per cent. acetic acid and 3 parts of a saturated solution of ferric acetate in glacial acetic acid, staining for 5-30 minutes and then mounting in lactophenol.

Trematodes are treated like cestodes, but if greater extension is required, they should be placed between glass slides pressed together by rubber bands. Such bands are conveniently made by cutting 2 mm. lengths off ordinary rubber tubing.

Acanthocephala should be pressed between glass slides, in order to get the proboscis extended, and so fixed in 70 per cent. alcohol.

Small worms of all kinds are usually of great importance and should not be missed. After the large worms have been removed the intestine is cut into convenient lengths, and each is vigorously shaken in a dish of warm water, collecting the worms that are liberated. It is then examined with a lens to see if small tapeworms are present, and these must be dissected out, after which the mucosa is scraped off into a dish of water and the scrapings searched for other small worms, holding the dish over a dark background.

Fæces containing eggs are fixed by mixing them with an equal quantity of hot 10 per cent. formalin. Cold formalin can be used, but the eggs of ascarids may continue to develop in the fixative. The material should be transferred gradually to 70 per cent. alcohol if it is to be kept for an indefinite period.

COLLECTION AND PRESERVATION OF ARTHROPOD PARASITES

Specimens for dry mounting, like adult *Diptera*, are killed in a cyanide killing bottle, made by placing into a wide-mouthed bottle a freshly made paste of potassium cyanide and plaster of paris, which is covered with a few layers of blotting paper. Strips of paper are placed into the bottle to prevent the insects from clinging together and damaging their appendages. They are set out on a mounting board in the ordinary way and then pinned down in boxes, of which the floors are covered with a mixture of wax and naphthalin. Some material should also be collected in 70 per cent. alcohol for making mounts of important parts.

Dipterous larvæ, lice, fleas, mites, etc., are fixed and stored in 70 per cent. alcohol or 10 per cent. formalin. Care must be exercised not to miss the small parasites, and it may be necessary to make deep skin scrapings of affected areas in order to find them.

Ticks can be preserved in their natural colours by dropping them alive into a carefully made solution of chloroform in 10 per cent. formalin. The formalin should be made up with distilled water. Chloroform is added in slight excess; the mixture is shaken and left for a few minutes to settle, and then the solution is poured off into a bottle with a well-fitting glass stopper. The live ticks are dropped in and the bottle is left well closed for about a month.

MAKING OF PERMANENT PREPARATIONS

Canada balsam is an excellent mounting medium, but requires careful and tedious preparation of the material by passing it through increasing concentrations of alcohol to draw out all water, during which shrinkage, especially of nematodes, is difficult to avoid. Glycerin gelatin is simpler, but also frequently causes shrinkage. It is very useful for eggs and small nematodes that tend to become too transparent in other media.

For all unstained material, like nematodes, tapeworm heads, acanthocephala and arthropods, the most suitable medium is the following mixture: gum arabic 60, glycerin 40, chloral hydrate 100, distilled water 100, and thymol 1. The specimens are transferred from 70 per cent. alcohol into 50 per cent. glycerin and then mounted in the gum arabic medium. Arthropod material, like heads of flies, whole fleas, etc., must first be boiled in 10 per cent. KOH solution to remove the soft internal parts, and it is usually necessary to puncture the body for this purpose. They are then washed in water and transferred to 70 per cent. alcohol, etc.

To bleach and soften the chitinous parts of Arthropoda, as a preliminary for the purpose of preparing sections, Roberts* recommends placing the material for a few hours in a strong solution of potassium chlorate to which some concentrated hydrochloric acid is added. The material can then be transferred to 70 per cent. alcohol. The soft parts are destroyed, except the muscles. Sections are made in celloidin or paraffin wax.

While nematodes are usually examined in lactophenol, into which they can be placed from 70 per cent. alcohol, cestodes and trematodes have to be stained so that the internal organs can be seen, and the preparation is mounted in balsam in the ordinary way. Various stains are employed, *e.g.* Delafield's hæmatoxylin, Ehrlich's acid hæmatoxylin, acid alum carmine, lithium carmine and hæmalum with 2 per cent. acetic acid. It is usually advisable to dilute the stain considerably with distilled water and to stain for a prolonged period, rather than to use the concentrated stain. The specimens should be slightly overstained and differentiated in a 1 per cent. acid alcohol or alum solution.

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* *Ann. Trop. Med. Par.*, 21 (1): 11-22. 1927.

CLINICAL DIAGNOSTIC METHODS

The veterinary student is taught to make a systematic and complete examination of an animal with a view to arriving at an accurate diagnosis. The examination of blood, fæces, urine, etc., is carried out when there are indications that this is necessary. The diagnostic methods described here should be included to form a part of the ordinary routine examination, and should be applied like all other parts of the usual procedure.

1. **The outside of the body** is searched for external parasites or their eggs (bots, oxyurids), not only on the surface but also in the ears and in the conjunctival sac (eye-worms), and the skin should be palpated to determine the presence of subcutaneous larvæ. If mange-like lesions are present, scrapings are made and examined in the following way: the material is boiled for a few minutes in 10 per cent. NaOH until the hairs are broken up, and then centrifuged. The sediment can be examined directly or it is centrifuged again with equal parts of glycerin and water, after which the mites will usually float on top. If a negative result is obtained with the latter procedure, the specific gravity of the fluid may have been too low and the sediment must be examined. Another method, which is useful if not many hairs are present, is to clear the material in clove oil or creosote and examine it directly.

2. All **excretions** of the body may be carriers of parasite eggs or larvæ. The nasal discharge and the sputum may, therefore, aid in the diagnosis of parasites in the air-passages, the vomit may bear evidence of parasites in the stomach, and the urine may contain eggs which can be concentrated by centrifuging. The fæces are by far the most important, as the eggs or larvæ of all gastro-intestinal parasites and many others leave the body in this vehicle. It should be remembered, however, that no eggs may be found if the worms are still immature or if only males are present. In some cases abnormally shaped eggs may be found.

Fæces are examined in the first place for ripe segments of tapeworms and the student should be familiar with their appearance, otherwise he may be at a loss to recognise these bodies. If a tapeworm infection is suspected, a purgative may be given to cause the expulsion of segments in case they are not readily found.

Birds that have cæca, like the fowl, pass two kinds of fæces, those from the small intestine being relatively coarse, loose and contain particles of varying colour, while those from the cæca are of a fine, pasty nature with a homogeneous brown or brownish-green colour. The eggs of small-intestinal worms will be found in both types of fæces, while those of cæcal worms are found only in the cæcal fæces.

Various methods are employed for detecting eggs in fæces; the following are a few simple ones:

(*a*) *The Direct Smear.*—A small quantity of fæces is placed with a toothpick on a slide, mixed with a drop of water, spread out and examined directly. At least three slides from different parts of the fæcal sample should be examined. This method is suitable for a very rapid examination, but will usually fail to detect weak infections.

(*b*) *Concentration Methods.*—The purpose of these methods is to detect light infections as well as others and to save time by concentrating the eggs in a small volume and by eliminating the trouble caused by large fæcal particles. Advantage is taken of the low specific gravity of most helminth eggs to separate them from the fæces, as described below. Many different methods have been suggested, but it is considered that, for the purposes of the veterinary student or practitioner, the selection of a few simple methods for regular use is more important than an exposition of all known methods.

In the *Willis technique* about 1 c.c. of the mixed specimen is diluted with 10-20 c.c. of concentrated salt solution in a suitable narrow cylinder, which is filled to the top with the liquid. A clean slide is placed on the cylinder in contact with the liquid and left for about 30-45 minutes, after which it is carefully removed, inverted and examined under a low power of the microscope. This method is not suitable for eggs of trematodes and most cestodes, but shows the majority of nematode eggs in the sample.

By *centrifugal flotation* methods more time is saved and greater accuracy obtained. A fair sample, if possible 15-30 c.c. of stirred fæces, is well mixed with about 500 c.c. water and strained through a sieve of 1 mm. mesh, or better a set of sieves with mesh ranging from 3 mm. to 0·25 mm. The mixture is left to sediment for 10-15 minutes, and the supernatant fluid then poured off until the sediment is about to flow out. The latter is shaken up and a sample is poured into a centrifuge tube and mixed with an equal volume of glycerin. After centrifuging at about 1,000 revolutions for 1-2 minutes, the eggs will be floating at the top. They are removed by touching the surface with the end of a squarely cut glass rod and transferred to a slide for examination. Instead of glycerin, a concentrated solution of sugar can be used. This method will also not show eggs of most trematodes, but these can be found if a heavy waterglass solution is used instead of glycerin. Since this is, however, not always practicable unless such a solution is kept for the purpose, it is recommended that several drops of the remaining sediment be directly examined on a slide for trematode eggs. If schistosome eggs are expected, the fæces sample should first be fixed in formalin or spirit before mixing with water, to prevent the eggs from hatching.

The zinc sulphate method of Faust* and its modification by Summers† is somewhat more intricate, but very effective.

The fæces may also contain larvæ—for instance, those of lungworms. Such larvæ will be found by flotation methods as used for eggs. A simpler method for sheep fæces is to place a few pellets in a Petri dish containing a small quantity of water, when the larvæ will rapidly leave the pellets and can be found in the water. In the case of soft fæces the material is spread out in a Petri dish and several small holes are made by means of a glass rod going down to the bottom. The holes are filled with water and the larvæ migrate into them from the surrounding fæces.

The eggs of some worms can be recognised on account of their shape and size, and this fact is of great importance in making a specific diagnosis. The student should, therefore, become familiar with the eggs that may be found in the fæces of the different species of domestic animals, as well as with different objects that occur in fæces and may be mistaken for eggs or larvæ, as, for instance, pollen grains, plant cells or hairs, fungus spores and cysts of Protozoa. (See Plates I-VII.)

(*c*) *Egg-counting Technique.*—In order to obtain accurate information with regard to the severity of an infection, egg-counting methods, by means of which the exact number of eggs per gram of fæces can be determined, have been devised. ‡ The specimen is well stirred and two samples of 5 gm. each are weighed off into large test tubes graduated at 75 c.c. If the fæces are soft, weighing by difference has to be done. In other methods a certain volume of fæces is measured off by displacement, and the number of eggs per cubic centimetre is determined. The tubes are filled with decinormal caustic soda to the 75 c.c. mark and about ten large glass beads are added. The tubes are firmly closed and vigorously shaken until the fæcal particles are thoroughly broken up. It is often advantageous to set up the tubes in the afternoon and continue the process next morning, when the fæces will be soft. If much froth is produced in shaking, the tubes can be left for a while until it disappears. Light shaking will then suffice to mix the contents, and a sample is drawn off immediately by means of a pipette graduated at 0·15 c.c. This is spread out with a needle over an area of about 25 by 40 mm. on a slide, and all the eggs in it are counted under a low magnification and using a mechanical stage. It will be seen that the number of eggs obtained, multiplied by 100, gives the number per gram of fæces. The average of the two tubes should be taken.

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* *Journ. Par.*, 25 (3): 241-262. 1939.

† *Journ. Par.*, 28 (4): 345-346. 1942.

‡ *Amer. Journ. Hyg.*, 8 (6): 902-909. 1928.

PLATE I

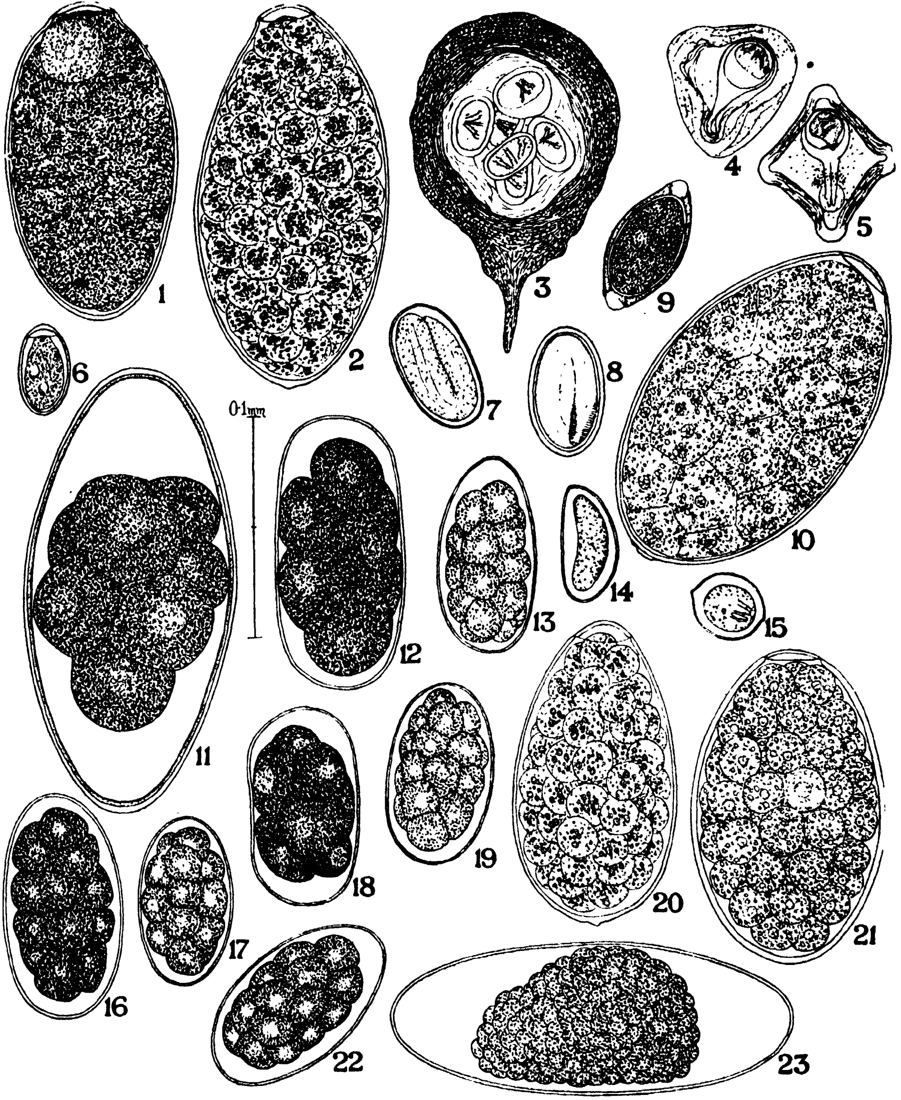

FIG. 1.—EGGS OF WORM PARASITES OF THE SHEEP. (ORIGINAL.)

1, *Fasciola hepatica;* 2, *Paramphistomum cervi;* 3, *Thysaniezia giardi;* 4, *Moniezia expansa;* 5, *Moniezia benedeni;* 6, *Dicrocœlium dendriticum;* 7, *Strongyloides papillosus;* 8, *Gongylonema pulchrum;* 9, *Trichuris globulosa;* 10, *Fasciola gigantica;* 11, *Nematodirus spathiger;* 12, *Gaigeria pachyscelis;* 13, *Trichostrongylus* spp.; 14, *Skrjabinema ovis;* 15, *Avitellina centripunctata;* 16, *Chabertia ovina;* 17, *Hæmonchus contortus;* 18, *Bunostomum trigonocephalum;* 19, *Œsophagostomum columbianum;* 20, *Cotylophoron cotylophorum;* 21, *Fascioloides magna;* 22, *Ostertagia circumcincta;* 23, *Marshallagia marshalli.*

PLATE II

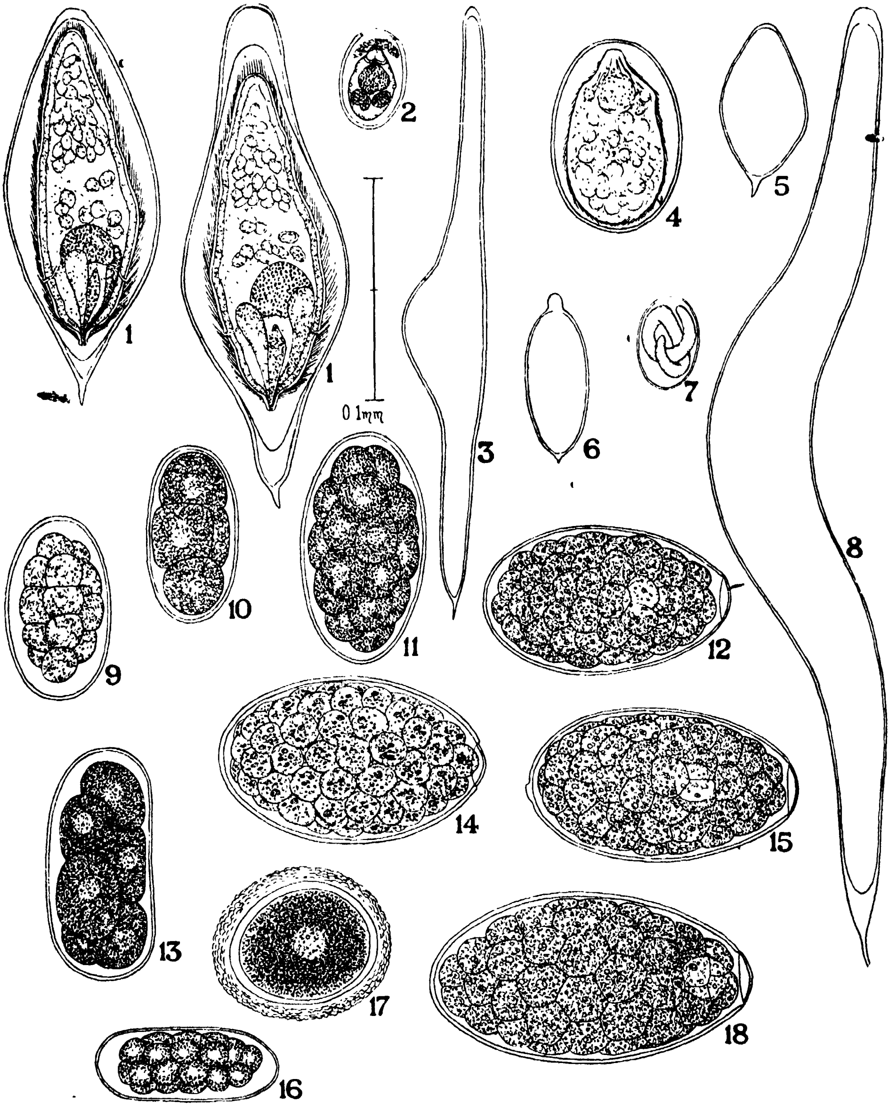

FIG. 2.—EGGS OF WORM PARASITES OF CATTLE. (ORIGINAL.)

1, *Schistosoma bovis;* 2, *Eurytrema pancreaticum;* 3, *Schistosoma spindalis;* 4, *Schistosoma japoncium;* 5, *Schistosoma indicum;* 6, *Ornithobilharzia turkestanicum;* 7, *Thelazia rhodesii;* 8, *Schistosoma nasalis;* 9, *Œsophagostomum radiatum;* 10, *Syngamus laryngeus;* 11, *Mecistocirrus digitatus;* 12, *Fischœderius cobboldi;* 13, *Bunostomum phlebotomum;* 14, *Carmyerius spatiosus;* 15, *Gastrothylax crumenifer;* 16, *Cooperia pectinata;* 17, *Ascaris vitulorum;* 18, *Fischœderius elongatus.*

PLATE III

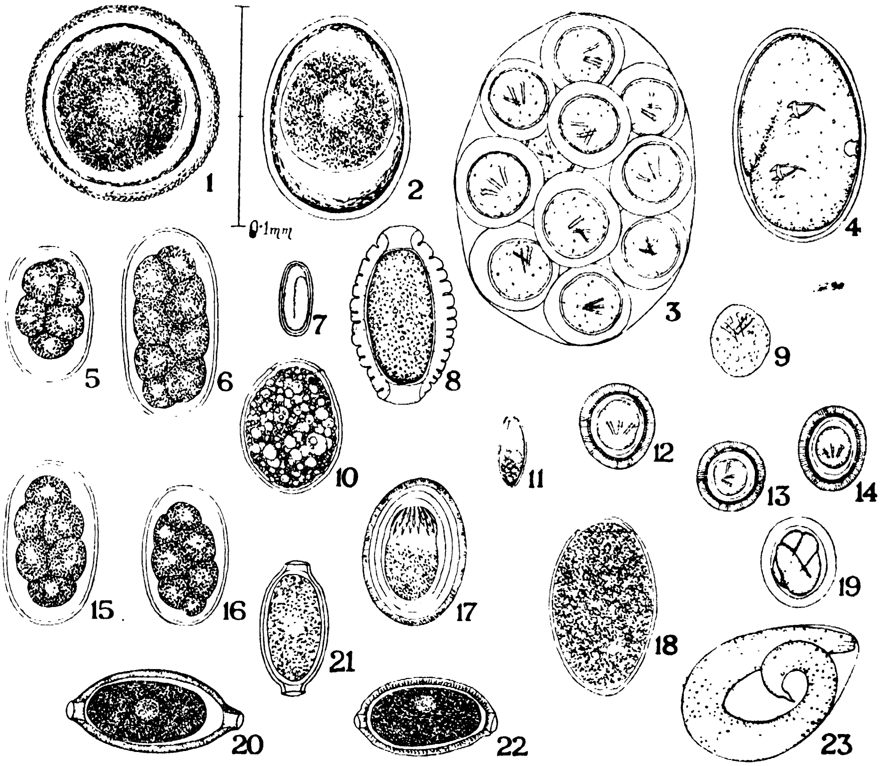

Fig. 3.—Eggs of Worm Parasites of the Dog and Fox. (Original.)

1, *Toxocara canis;* 2, *Toxascaris leonina;* 3, *Dipylidium caninum;* 4, *Linguatula serrata;* 5, *Ancylostoma caninum;* 6, *Ancylostoma braziliense;* 7, *Spirocerca lupi;* 8, *Dioctophyma renale;* 9, *Mesocestoides lineatus;* 10, *Diphyllobothrium latum;* 11, *Euryhelmis squamula;* 12, *Echinococcus granulosus;* 13, *Tænia hydatigena;* 14, *Tænia ovis;* 15, *Uncinaria stenocephala;* 16, *Necator americanus;* 17, *Onicola canis;* 18, *Nanophyetus salmincola;* 19, *Physaloptera canis;* 20, *Trichuris vulpis;* 21, *Capillaria plica;* 22, *Capillaria ærophila;* 23, *Filaroides osleri.*

PLATE IV

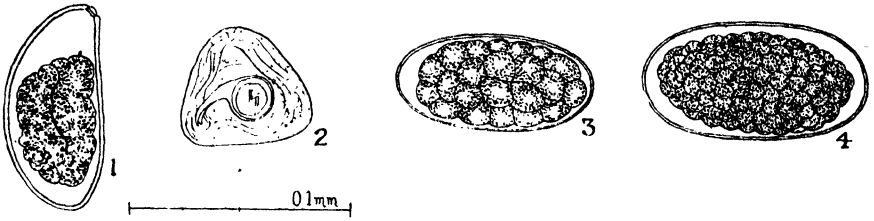

Fig. 4.—Eggs of Worm Parasites of the Rabbit. (Original.)

1, *Passalurus ambiguus;* 2, *Cittotænia ctenoides;* 3, *Trichostrongylus retortæformis;* 4, *Graphidium strigosum.*

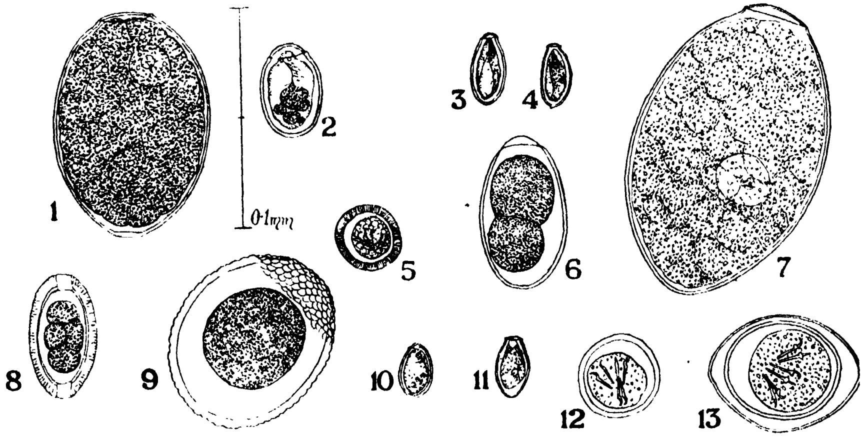

Fig. 5.—Eggs of Worm Parasites of the Cat. (Original.)

1, *Echinochasmus perfoliatus;* 2, *Platynosomum concinnum;* 3, *Opistorchis sinensis;* 4, *Opistorchis tenuicollis;* 5, *Tænia tæniæformis;* 6, *Gnathostoma spinigerum;* 7, *Euparyphium melis;* 8, *Capillaria hepatica;* 9, *Toxocara mystax;* 10, *Heterophyes heterophyes;* 11, *Metagonimus yokogawai;* 12, *Diplopylidium zschokkei;* 13, *Joyeuxiella furhmanni.*

PLATE V

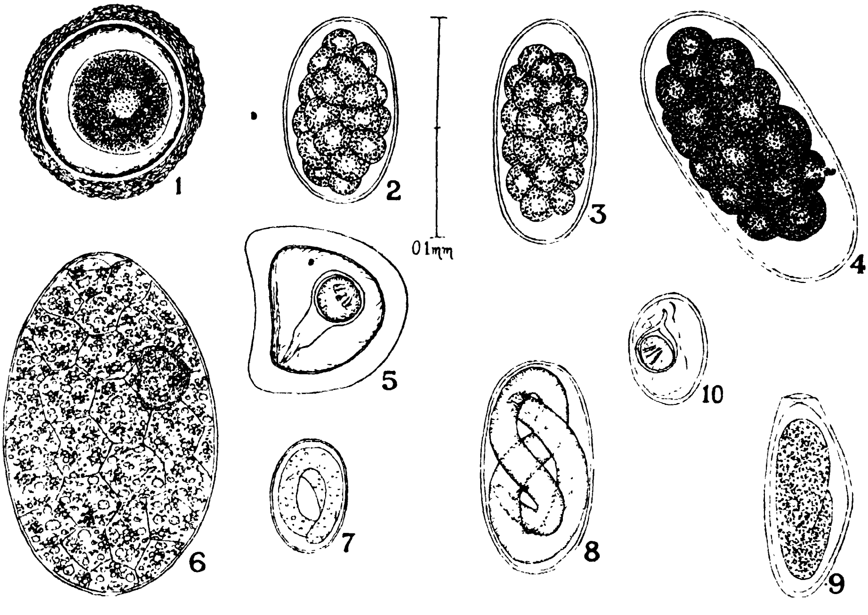

FIG. 6.—EGGS OF WORM PARASITES OF EQUINES. (ORIGINAL.)

1, *Ascaris equorum;* 2, *Strongylus* spp.; 3, *Trichonema* spp.; 4, *Triodontophorus tenuicollis;* 5, *Anoplocephala* spp.; 6, *Gastrodiscus ægyptiacus;* 7, *Strongyloides westeri;* 8, *Dictyocaulus arnfieldi;* 9, *Oxyuris equi;* 10, *Paranoplocephala mamillana.*

PLATE VI

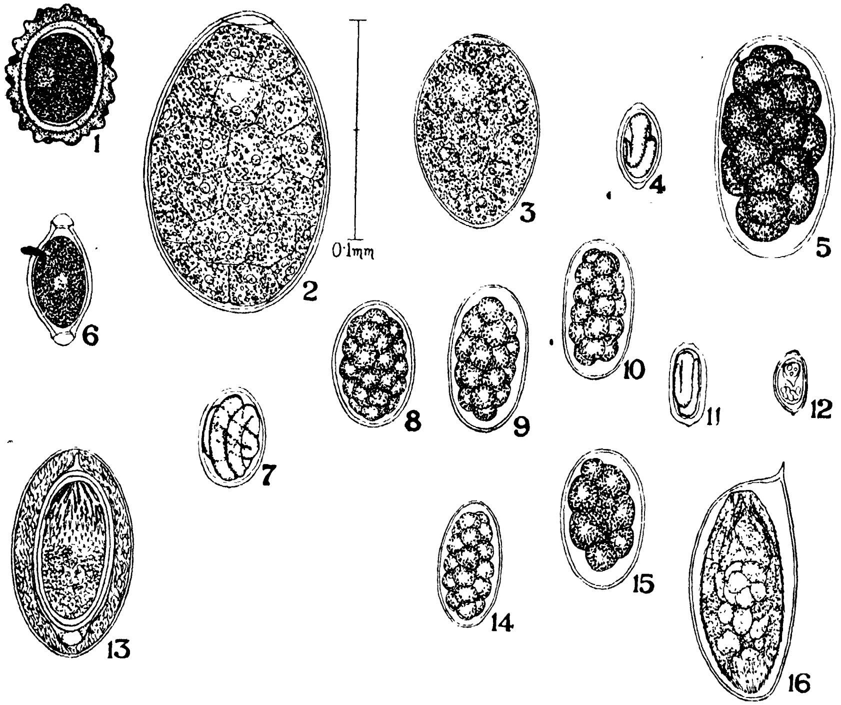

Fig. 7.—Eggs of Worm Parasites of the Pig. (Original.)

1, *Ascaris lumbricoides;* 2, *Fasciolopsis buski;* 3, *Paragonimus westermanii;* 4, *Ascarops strongylina;* 5, *Stephanurus dentatus;* 6, *Trichuris trichiura;* 7, *Metastrongylus apri;* 8, *Bourgelatia diducta;* 9, *Œsophagostomum dentatum;* 10, *Hyostrongylus rubidus;* 11, *Physocephalus sexalatus;* 12, *Brachylæmus suis;* 13, *Macracanthorhynchus hirudinaceus;* 14, *Globocephalus connorfili;* 15, *Necator* sp.; 16, *Schistosoma suis.*

PLATE VII

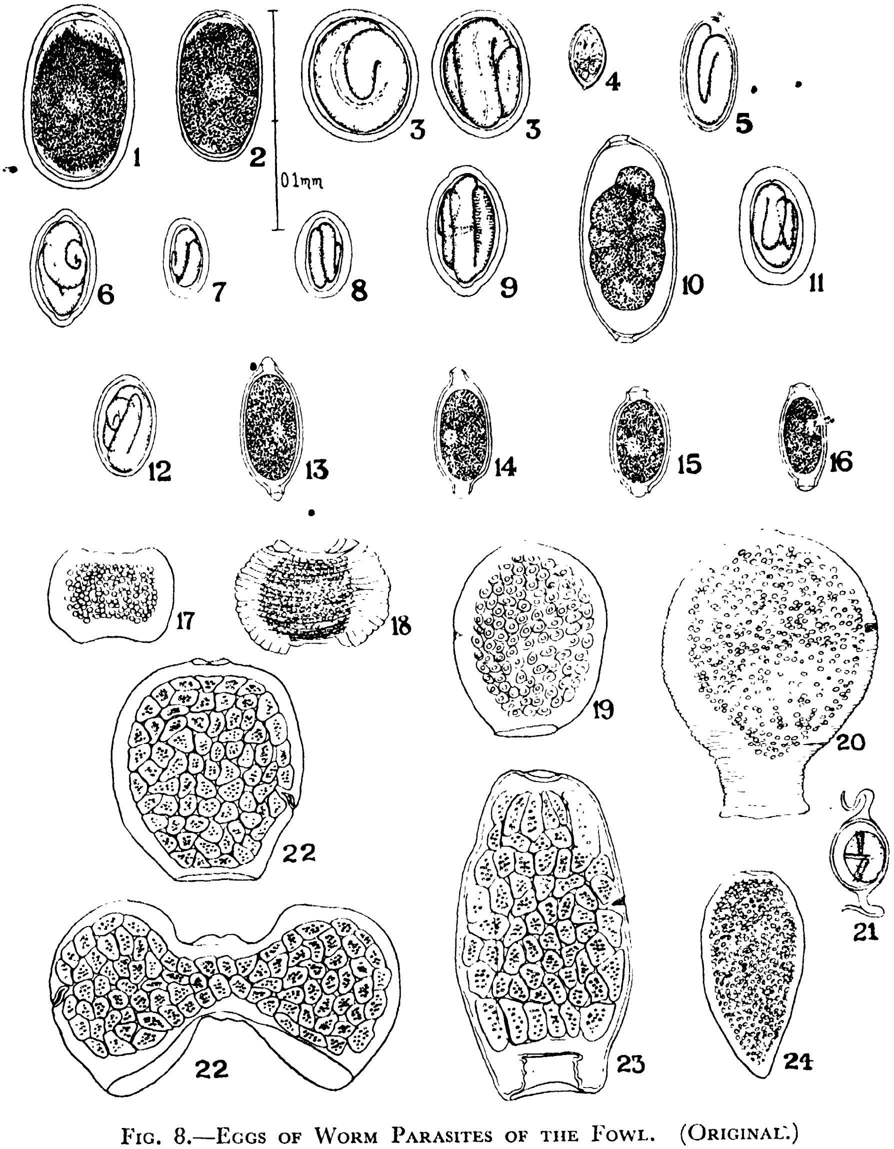

Fig. 8.—Eggs of Worm Parasites of the Fowl. (Original.)

1, *Ascaridia galli;* 2, *Heterakis gallinæ;* 3, *Subulura brumpti;* 4, *Prosthogonimus* sp.; 5, *Strongyloides avium;* 6, *Tetrameres americana;* 7, *Acuaria spiralis;* 8, *Acuaria hamulosa;* 9, *Gongylonema ingluvicola;* 10, *Syngamus trachea;* 11, *Hartertia gallinarum;* 12, *Oxyspirura mansoni;* 13, *Capillaria annulata;* 14, *Capillaria retusa;* 15, *Capillaria columbæ;* 16, *Capillaria longicollis.* Ripe segments of tapeworms (not drawn to scale); 17, *Amœbotænia sphenoides;* 18, *Hymenolepis carioca;* 19, *Raillietina cesticillus;* 20, *Choanotænia infundibulum;* 21, single egg of *C. infundibulum;* 22, *Raillietina echinobothrida;* 23, *Raillietina tetragona;* 24, *Davainea proglottina.*

The pipettes are best made for the purpose by drawing out glass tubing in such a way that the drawn portion has a bore of about 2 mm., and can hold at least 0·15 c.c. The graduation must be done accurately. In the case of horse fæces the mixture must, after comminution, be carefully strained through a sieve of 1 mm. mesh, as the large grass particles would otherwise block the pipette.

In another egg-counting method, devised by Gordon and Whitlock,* visibility of the eggs is improved by flotation, while a counting chamber obviates the use of a pipette for accurate measurement of samples. The counting chamber is made of two glass slides, separated by four narrow, transversely-placed strips of glass 1·5 mm. thick, so that three spaces of 1·5 mm. depth are obtained between the two slides. On the upper slide an area of 1 sq. cm. is ruled over each space. The volume underneath this ruled area will therefore be 0·15 c.c. From the mixed samples of fæces a 2 gm. quantity is weighed off and soaked in 30 c.c. water until sufficiently soft. To this is added 30 c.c. saturated salt solution and some steel ball bearings. After thorough shaking a sample is withdrawn by means of a wide (8 mm.) pipette and run into the counting chamber, filling all three spaces. The eggs rise to the top, so that they are all in focus against the upper slide. The number of eggs within the ruled area, multiplied by 200, represents the number per gram in the original sample. Three counts are made and the mean taken.

It is obvious that the count will be influenced by the consistency of the fæces, wet fæces being much heavier than a drier specimen, and further by the total amount of fæces passed per day, since the eggs would be concentrated in a smaller output of fæces. The first factor should be taken into account, and the number of eggs obtained is multiplied by a fixed factor for each grade of consistency according to some methods; but this presents many difficulties, and a more satisfactory procedure is to multiply the count per gram by the total weight of the fæces passed in 24 hours, thus obtaining the total egg output per day. If this is done for 3 consecutive days, the average obtained is a very fair measure of the infection, and can be used for accurate experimental work—for instance, the testing of anthelmintics. Since various factors like diet or the actual number of parasites present have a marked influence on the egg-output per female, the number of worms cannot be accurately estimated from the number of eggs in the fæces.

(*d*) *Fæces Cultures.*—Since a specific diagnosis cannot always be made from the eggs, it may be necessary to cultivate the larvæ from those eggs that hatch in the free state. For this purpose the fæces are broken up and placed in a glass jar, which is firmly closed and kept at a temperature of about 26° C. for a suitable time, usually 7 days. The fæces must be neither too dry nor too wet; the consistency of normal sheep and horse fæces is the corrrect one. If they are too dry, the fæces are moistened with water; if too wet, sterilised and dried sheep fæces are added or a good grade of animal charcoal can be used instead. After incubation the jar is placed in a dull light and many species of larvæ will migrate up the walls of the jar, from which they can be removed by means of a needle for examination in a drop of water on a slide. It is advisable to kill the larvæ by heating carefully over a small flame until movement ceases and the worms lie fully extended.

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* *Journ. Counc. Sc. Ind. Res.,* 12 (1): 50-52. 1939.

Larvæ that do not migrate can be separated by means of the Baermann technique as follows: a glass funnel 20 cm. wide at the top and closed at the bottom with a clamped piece of rubber tubing is fixed in a stand and a circular piece of wire gauze, about 9 cm. in diameter, is placed in the funnel and on it a larger piece of linen. The incubated fæces are spread 2 cm. deep on the linen, and water at 40° C. is poured down the side of the funnel until it covers the fæces. The apparatus is left for 12 hours, when the larvæ will be found in a few c.c. of water drawn off at the bottom. This method was devised for the separation of larvæ from soil and is very useful for that purpose as well.

Another culture method which gives good results, for instance with dog fæces, is to mix equal parts of fæces and charcoal, placing the mixture in a Petri dish and in the lid of the dish a piece of moist blotting paper. The larvæ will later be found on the paper.

For culturing the larvæ of *Strongyloides stercoralis* which infect man by penetrating through the skin, an excellent method has been devised by Fülleborn* to protect the worker and to produce masses of larvæ free from debris.

3. **Blood Examination for Larvæ.**—The larvæ of most filarial worms are found in the blood, and the diagnosis of filariasis has to be made by finding them. Several methods may be employed:

(*a*) A drop of fresh blood is placed on a slide, covered with a cover-slip and examined immediately. The microfilariæ will be seen moving about. This method can be carried out as a preliminary, but is not suitable for a specific determination. A few slides examined in this way will show whether larvæ are present and, since the larvæ of some species occur in the blood at night and others during the day, it is necessary to carry out the examination at the correct time.

(*b*) If the larvæ are abundant, a thin smear can be made; if they are rare, a thick film is made and this gives better results in all cases. The films are completely air-dried as quickly as possible and the thick film is then placed into a vessel of distilled water in a slanting position and facing downwards, until it has been completely dehæmoglobinised. It is then air-dried again and fixed in methyl alcohol for ten minutes. Both types of films are stained in Böhmer's hæmatoxylin, which is preferable to Giemsa's stain for this purpose.

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* *Arch. f. Schiffs- u. Tropenhyg.*, 28: 144-165. 1924.

A method which is especially useful if the " fixed points " (p. 255) of the larvæ have to be measured is given by Fülleborn. The thick film, freshly dried or not more than a few days old, is dehæmoglobinised and stained for one hour in physiological saline which contains per 100 c.c. 0·2 gm. methyl green and 0·075 gm. pyronin. It is then very rapidly dehydrated in increasing concentrations of alcohol, cleared in xylol and mounted in canada balsam. The sheath is not stained by this method.

(*c*) When the microfilariæ are rare, several c.c. of blood are placed in a centrifuge tube and 5 per cent. acetic acid is added to produce hæmolysis. When this is complete, the mixture is centrifuged and the larvæ are removed from the bottom by means of a pipette. Fülleborn* recommends mixing the blood with several volumes of 95 parts 5 per cent. formalin, 5 parts glacial acetic acid and 2 parts concentrated solution of gentian violet in alcohol, which hæmolyses the red corpuscles and fixes and stains the larvæ. This method is specially recommended for measuring the total length of the larvæ.

4. **Allergic Reactions.**—In the same way that the body develops antibodies against a bacterial infection it develops antibodies as a result of the presence of metazoan parasites. Some of the antibodies in the latter case are, however, not as specific as those produced by bacterial antigens, and this detracts much from the value of serological reactions for the diagnosis of parasitic diseases, especially in domestic animals, which rarely harbour only one species of parasite, but rather a number of species at the same time. Although such reactions are frequently used in the case of man, they have not yet found a useful application in the field of veterinary science. Some of the more common methods will briefly be discussed here, but it must be remembered that the diagnosis should always rather be based on the eggs or larvæ or the worms themselves, and that some of the allergic reactions may be obtained for a long time after the parasites have left the body.

(i.) *Intradermal Reactions.*—One of the oldest tests is the Casoni reaction for the diagnosis of Echinococcus infection. The usual antigen is hydatid fluid taken by aseptic puncture from cysts in the lungs or livers of slaughtered animals, but extracts made from the heads occurring in the cysts or even the fluid from other species of cysticerci (*C. tenuicollis*) have also been used. The antigen is injected into the skin of the arm. In positive cases a wheal forms at the site of injection in a very short time and extends outwards, reaching its maximum in about 15 minutes, and then it gradually disappears, being usually followed by induration and reddening of the area. This reaction is not sufficiently specific to be completely reliable, as positive reactions are sometimes also obtained in patients with skins that are sensitive to other helminths, and a negative reaction is therefore more significant than a positive one.

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* In Kolle and Wasserman, *Handb. der Pathog. Mikroorg.*, 6 (28): 1053. 1929.

Another method is the application of powdered worm material to the scarified skin, as recommended by Fülleborn.* In the case of *Strongyloides* infection this author has obtained good results from the use of powdered larvæ. Fairley† has used the livers of snails infected with schistosome cercariæ as antigen in tests for schistosome infection. This method has also been used for other worm infections, but has the same disadvantages as the Casoni reaction. The skin, moreover, usually does not become sensitive until some time after the parasites have established themselves in the host.

(ii.) *Complement fixation* has been employed in many cases; for instance, for detecting Echinococcus, schistosome and liver-fluke infections. It is considered by most experimenters to be less satisfactory for Echinococcus than the Casoni reaction. In the case of schistosomiasis the test is of special value during the early period of the disease, when eggs are not yet being passed. This reaction is also not sufficiently specific to be completely reliable.

(iii.) The *precipitin reaction* is more rarely employed, but has been used, for instance in schistosomiasis.

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* *Arch. f. Schiffs- u. Tropenhyg.*, 30: 732-749. 1926. *Klin. Wschr.*, 7 (17): 820. 1928.

† *Med. Journ. of Australia*, December, 1927, 812-818.

SECTION III

HELMINTH PARASITES

THE parasitic helminths are contained in the following groups of invertebrates:

PHYLUM **PLATHELMINTHES**
  CLASS **TREMATODA** (Flukes)
  CLASS **CESTODA** (Tapeworms)

PHYLUM **NEMATHELMINTHES**
  CLASS **NEMATODA** (Roundworms)
  CLASS **NEMATOMORPHA** (Horse-hair worms)
  APPENDIX **ACANTHOCEPHALA** (Thorny-headed worms)

PHYLUM **ANNELIDA**
  CLASS **HIRUDINACEA** (Leeches).

The name Helminth was primarily used to denote worms of the phyla Plathelminthes and Nemathelminthes, but has acquired a wider sense, being now generally used for all worm parasites, and includes those groups enumerated above. The knowledge relating to these worms constitutes the science of Helminthology.

CLASS TREMATODA

Usually flat, leaf-shaped, parasitic worms without a body-cavity; provided with a branched excretory system; alimentary canal usually without an anus; as a rule hermaphrodite, and the development is direct or includes the passage through one or two intermediate hosts, of which the first is a mollusc in all known cases.

Morphology.—Although most trematodes are flat dorso-ventrally and leaf-shaped like *Fasciola*, some are more cylindrical and others conical (*Paramphistomum*), while *Schistosoma* is elongate and more " worm-like " than other Trematodes.

The body is covered with a cuticle which is smooth or spiny and is formed as a secretion of certain cells which lie underneath it. A body-cavity is absent, and the internal organs lie in a spongy tissue formed of branched cells, known as the "parenchyma." There are several sets of muscle fibres, their arrangement being circular, longitudinal, diagonal and dorso-ventral, and all except the last group lie directly underneath the cuticle.

Organs of adhesion in the form of cup-shaped suckers are present in most trematodes. In many cases there are two, one anterior and surrounding the oral opening and the other ventral or posterior. These suckers are strongly muscular organs and, in many of the ectoparasitic trematodes, they bear hooks.

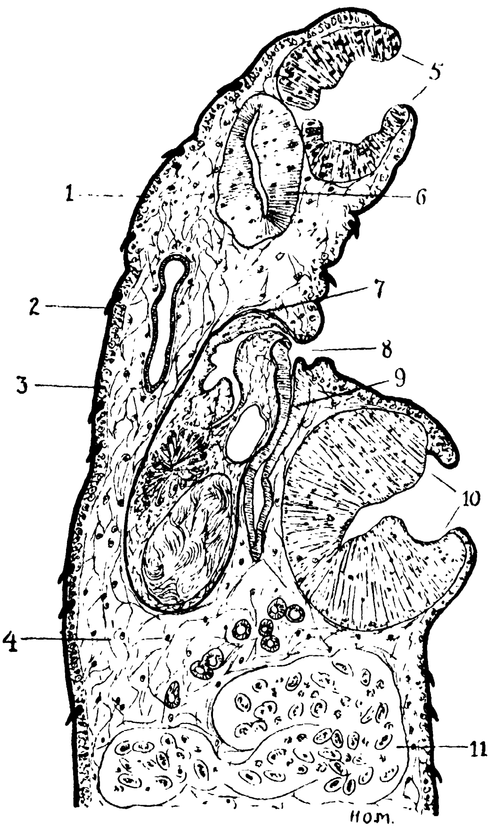

FIG. 9.—LONGITUDINAL SECTION THROUGH *Fasciola hepatica*. (AFTER MÖNNIG.)

1, Cuticle; 2, cuticular spine; 3, subcuticular cells; 4, parenchyma; 5, oral sucker; 6, pharynx; 7, cirrus sac; 8, genital sinus; 9, metaterm; 10, ventral sucker; 11, uterus with eggs.

The mouth usually opens into a muscular pharynx, sometimes preceded by a pre-pharynx, and is followed by an œsophagus which leads into the intestine. The latter usually divides into two branches which end blindly, although a few species have an anus. The two intestinal branches may be provided with side-branches, as in *Fasciola*. They divide the body into central and lateral regions.

The excretory system consists of a bladder which is sac-like in its simplest form, but may have various shapes, and usually opens at the posterior extremity of the body. From this central collecting organ branched tubes run out into the parenchyma, ending in terminal organs which are characteristic of the flatworms and are known as flame-cells. These cells have a basal cytoplasmic portion which contains the nucleus and bears a number of long cilia that lie in the proximal wide part of the tube which is attached to the cell. The flame-cell is the excretory cell, collecting from its surroundings the waste products to be excreted, while its cilia produce a current in the tubes and so propel these substances to the bladder. The latter gradually fills and ejects the contents at intervals. The flame-cells can best be seen in live cercariæ placed under a cover-slip to which slight pressure is applied.

The nervous system is composed of a circum-œsophageal ring of fibres and ganglia, from which a number of nerves run forwards and backwards to all parts of the body. Sense organs as such are not present in the adult, although the free-living larval forms (miracidium and cercaria) may be provided with patches of pigment called " eye-spots."

With the exception of the *Schistosomatidæ*, the trematodes are hermaphrodite. The male organs consist as a rule of two testes which may be spherical, lobed, branched or divided into a number of smaller bodies. The vasa efferentia unite to form the vas deferens, which usually widens distally and forms a vesiculum seminalis surrounded by the prostate gland, and then ends in the cirrus, a protrusible portion which may be armed with spines. There may be a cirrus-sac enclosing these terminal organs. The genital pore is usually anterior and ventral, but may be posterior or lateral. It is surrounded by a genital sinus or atrium which is sometimes developed into a sucker and in which the female pore is also situated. Self-fertilisation usually takes place; the cirrus is evaginated and enters the uterus, or the genital sinus is closed and communication is established in this way.

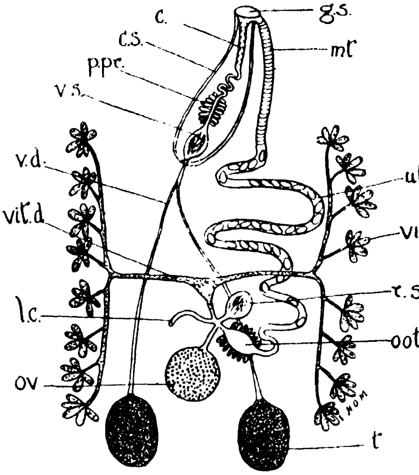

Fig. 10.—Reproductive Organs of a Trematode: Diagrammatic. (Original.)

c., Cirrus; *c.s.*, cirrus-sac; *g.s.*, genital sinus; *l.c.*, Laurer's canal; *m.t.*, metaterm; *oot.*, oötype surrounded by Mehlis' gland; *ov.*, ovary; *p.pr.*, pars prostatica; *r.s.*, receptaculum seminis; *t.*, testis; *ut.*, uterus; *v.d.*, vas deferens; *v.s.*, vesiculum seminalis; *vit.*, vitellaria; *vit.d.*, vitelline duct.

The female organs consist of an ovary which is usually slightly lobed and discharges the ova into the oviduct. The latter frequently bears a receptaculum seminis and a narrow canal opening on the dorsal surface of the body, known as Laurer's canal, which is perhaps homologous with the vagina of the cestodes, but does not function in copulation. In ectoparasitic forms a vagino-intestinal canal is present. There is a paired vitelline or yolk gland, consisting usually of a number of follicles situated laterally in the body and discharging into the yolk duct, which joins the oviduct in a special wide portion, the oötype, in which the eggs are formed. The oötype is surrounded by a gland, called Mehli's gland or incorrectly the shell-gland. The shells are formed from material contributed by the vitelline glands. On leaving the oötype the eggs enter the uterus, which may be short or much convoluted and opens at the genital pore. In some cases the distal part of the uterus forms a wide portion or metaterm. The eggs are usually provided with an operculum, and in many cases develop in the uterus, so that they are ready to hatch when laid.

Development.—The Trematodes fall into two natural groups: the *Monogenea*, which have a direct life-cycle; and the *Digenea*, which require an intermediate host. The first group live chiefly as external parasites on fishes, while those that are important in veterinary medicine belong to the second group.

The eggs of the *Digenea* are usually passed in the fæces of the host and under suitable conditions a larva, called a *miracidium*, hatches out. The conditions required are chiefly moisture and warmth. The miracidium is as a rule roughly triangular in shape, broad anteriorly and narrow posteriorly. It is in most cases covered with a ciliated ectoderm, and may have an anterior spine for boring into the intermediate host. The miracidium is usually also provided with excretory and nervous systems and may have a sac-like gut and an eye-spot. Its body contains a cavity and a number of germinal cells attached to the walls. This larval stage does not feed and dies unless it finds a suitable snail within a few hours. It penetrates actively into the snail, casting off the ciliated coat, and becomes a simple sac-like structure called a *sporocyst*. The germinal cells now proceed to develop parthenogenetically into the following larval generation which are known as *rediæ*, and these in turn produce a further generation called *cercariæ*. In some cases, *e.g. Schistosoma*, the sporocyst produces cercariæ directly. The redia has an oral sucker, a pharynx, a sac-like intestine, an excretory system and a birth-pore, through which the next generation escapes. It may produce further generations of rediæ under certain conditions, for instance in winter. The cercaria has suckers and an intestine like the adult, excretory and nervous systems, special glands and sometimes an anterior spine. It is frequently also provided with a tail, by means of which it propels itself through the water after escaping from the snail.

The cercaria is the final larval stage and has to reach the definitive host in order to complete its life-cycle. It is the only larval stage which is infective for the final host. It enters the host by active penetration (*Schistosoma*) or with food and water. In the latter case the cercaria may encyst itself on plants, certain of its glands secreting a cement for fixation and others a protective cyst. Some cercariæ (these usually have an anterior spine) penetrate into a second intermediate host, which may be a fish, snail, frog, crab, etc., in which they again encyst and grow up to a certain stage known as a *metacercaria.* When the second intermediate host is ingested by the final host, infection of the latter takes place.

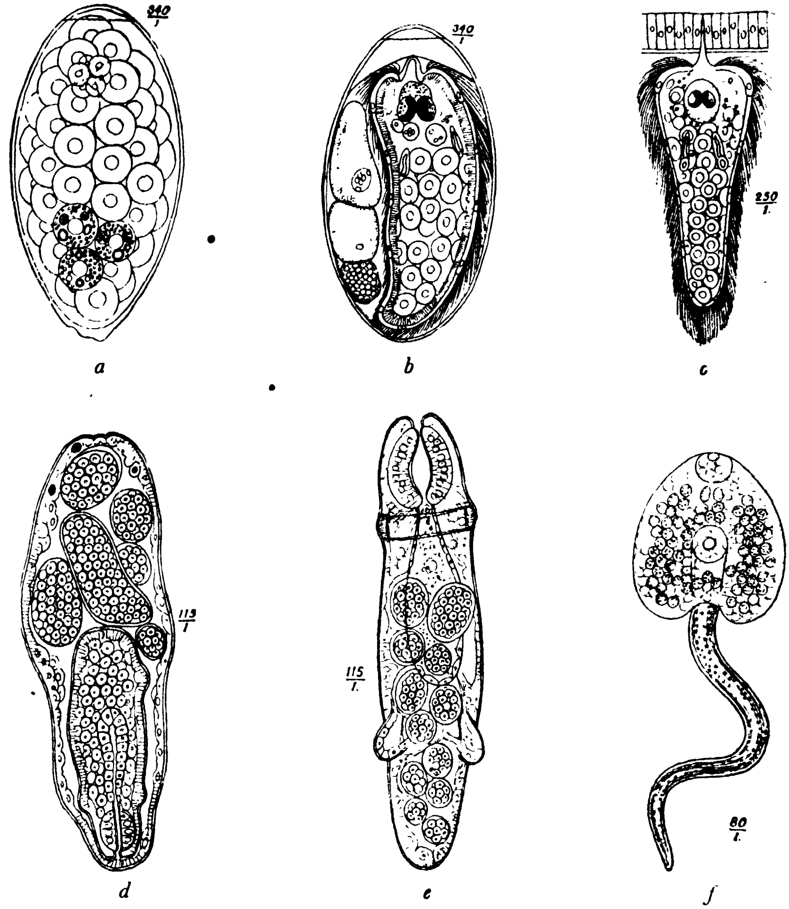

FIG. 11.—*Fasciola hepatica* DEVELOPMENT. (FROM BAYLIS, AFTER THOMAS.)
a, Egg; *b*, egg containing miracidium; *c*, miracidium; *d*, sporocyst; *e*, redia; *f*, cercaria.

When the encysted cercaria or metacercaria is swallowed by the final host it is protected against the acid juices of the stomach by the cyst wall and, on reaching the intestine, it becomes liberated and proceeds to the special part of the body in which the adult parasite normally lives. The route of migration in the body of the host is not known in all cases.

Classification of cercariæ according to Lühe:*

A. Body of cercaria with a strong, longitudinal undulating membrane. *Lophocercaria.*

B. Body without longitudinal membrane.

- I. Two symmetrical, slender caudal appendages which arise separately and are several times longer than the body. Oral aperture at middle of ventral surface. Intestine simple, sac-like. . . . . *Gasterostome cercaria.*
- II. Caudal appendage variable, absent or distally forked, but never split to the base. Oral aperture anterior. Intestine bifurcate.
  - (*a*) Ventral sucker absent. . . . . *Monostome cercaria.*
  - (*b*) Ventral sucker present.
    - 1. Ventral sucker posterior, immediately anterior to base of slender tail. . . . *Amphistome cercaria.*
    - 2. Ventral sucker anterior to hind end of body and well separated from base of tail if latter is present. . . . . *Distome cercaria.*

Distome cercariæ

A. Cercariæ single.

- I. Tail well developed.
  - (*a*) Body retractile into a chamber formed by base of tail. *Cystocercous cercaria.*
  - (*b*) Body not retractile into tail.
    - 1. Tail not bifurcate.
      - (*a*) Tail without bristles.
        - (i.) Tail contractile to equal or exceed width of body. *Rhopalocercous cercaria.*
        - (ii.) Tail always distinctly narrower than body. . . *Leptocercous cercaria.*
      - (*b*) Tail with bristles (marine). *Trichocercous cercaria.*
    - 2. Tail distally bifurcate. . . *Furcocercous cercaria.*
- II. Tail stumpy or absent.
  - (*a*) Tail stumpy. . . . . *Microcercous cercaria.*
  - (*b*) Tail absent. . . . . *Cercariæum.*

B. Cercariæ joined into a colony by their tapering tail ends (marine). *Rat-king cercariæ.*

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* *Süsswasserfauna Deutschlands*, H. 17. 1909.

Family DICROCŒLIIDÆ

These are small or medium-sized flukes, flattened, elongate, with weak musculature and loose parenchyma, and, therefore, the internal organs are easily seen. The suckers are not far apart. A pharynx and an œsophagus are present and the intestinal cæca are simple, not quite reaching the hind end. The excretory bladder is simple and tubular. The testes are situated not far behind the ventral sucker and the ovary is usually behind them. The genital pore opens in the middle line anterior to the ventral sucker. The cirrus is small. A Laurer's canal and a small receptaculum seminis are present. The vitelline glands are well developed, lateral and do not reach the hind end of the body. Most of the space behind the genital glands is filled by the uterus. Eggs numerous, deep brown in colour.

Genus **Dicrocœlium** (Dujardin, 1845)

D. dendriticum (Rudolphi, 1819) (syn. *D. lanceolatum*) occurs in the bile ducts of sheep, goat, cattle, deer, pig, dog, donkey, hare, rabbit, elk, coypu and rarely in man. It has a wide distribution, but has not been reported from Central and South Africa. The worm is 6-10 mm. long and 1·5-2·5 mm. wide. The body is elongate, narrow anteriorly and widest behind the middle. The cuticula is smooth. The oral sucker is smaller than the ventral. The testes are slightly lobed and lie almost tandem, immediately posterior to the ventral sucker, with the ovary directly behind them. The vitelline glands occupy the middle third of the lateral fields. Behind the gonads the central field is occupied by the transverse coils of the uterus, filled with brown eggs. The latter measure 36-45 by 22-30 μ and are operculate.

Life-Cycle.—The snails, *Zebrina detrita*, *Abida frumentum*, *Ena obscura*, *Theba carthusiana*, *Euomphalia strigella*, *Helicella candidula*, *H. ericetorum* and *H. itala*, are known as intermediate hosts. After the eggs of the fluke have been swallowed by the snail, the miracidia hatch in the snail's gut and migrate to the mesenteric gland, where they grow to polymorphous sporocysts lacking a distinct cuticle. These produce a second generation of sporocysts, provided with a cuticle and a birth pore, which in turn produce cercariæ, known as *Cercaria vitrina*. The cercariæ* emerge from the sporocysts only in damp weather following a dry spell and, in the pulmonary chamber of the snail, they clump together in masses of 200-

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* Mattes and Neuhaus, *Zschr. f. Par.*, 8 (4): 371-473. 1936.

400, held together by a sticky, gelatinous substance. These masses are expelled from the snail and adhere to the vegetation, with which they are swallowed by the grazing final hosts. The cercariæ* penetrate into the intestinal wall of the final host and pass to the liver via the portal circulation, where they stay in the veins for a week before breaking out and reaching the bile ducts. The young flukes develop in the small branches, the older ones go to the larger ducts. They are full grown after 7 weeks and the first eggs are laid 4 weeks later.

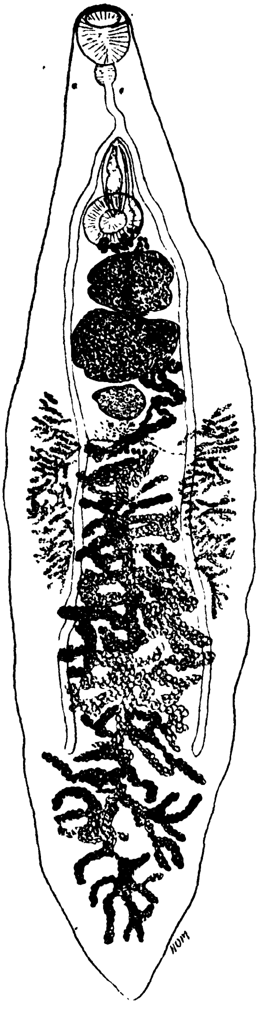

FIG. 12.—*Dicrocœlium dendriticum*, VENTRAL VIEW. (ORIGINAL.)

Pathogenesis and Symptoms.—These small flukes penetrate into the fine branches of the bile ducts, in which they lie greatly extended and attached by means of their suckers, causing a cirrhosis of the liver and the development of numerous fine streaks of connective tissue. They do not produce symptoms unless the infection is heavy, and they may occur in very large numbers. Perhaps a toxin is produced, but this is not definitely known. Since the worms are small and devoid of cuticular spines, they are not as pathogenic as *Fasciola hepatica*, but they cause somewhat similar symptoms and are frequently found together with the large liver-fluke.

Treatment.—Sprehn recommends two intramuscular injections on two successive days of 20 c.c. Fuadin each for adult sheep. Male-fern preparations are not as effective as against *Fasciola*, while carbon tetrachloride, an excellent drug for many blood-sucking flukes, is ineffective against *Dicrocœlium.*

Prophylactic measures have to be directed against the intermediate host, as in the case of *Fasciola* (p. 51).

Dicrocœlium hospes is a closely related form described by Looss from the gall-bladder of cattle in the Sudan. It also occurs in Nigeria and the Gold Coast.

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* Neuhaus, *idem*, 10: 476-512. 1938.

PLATE VIII

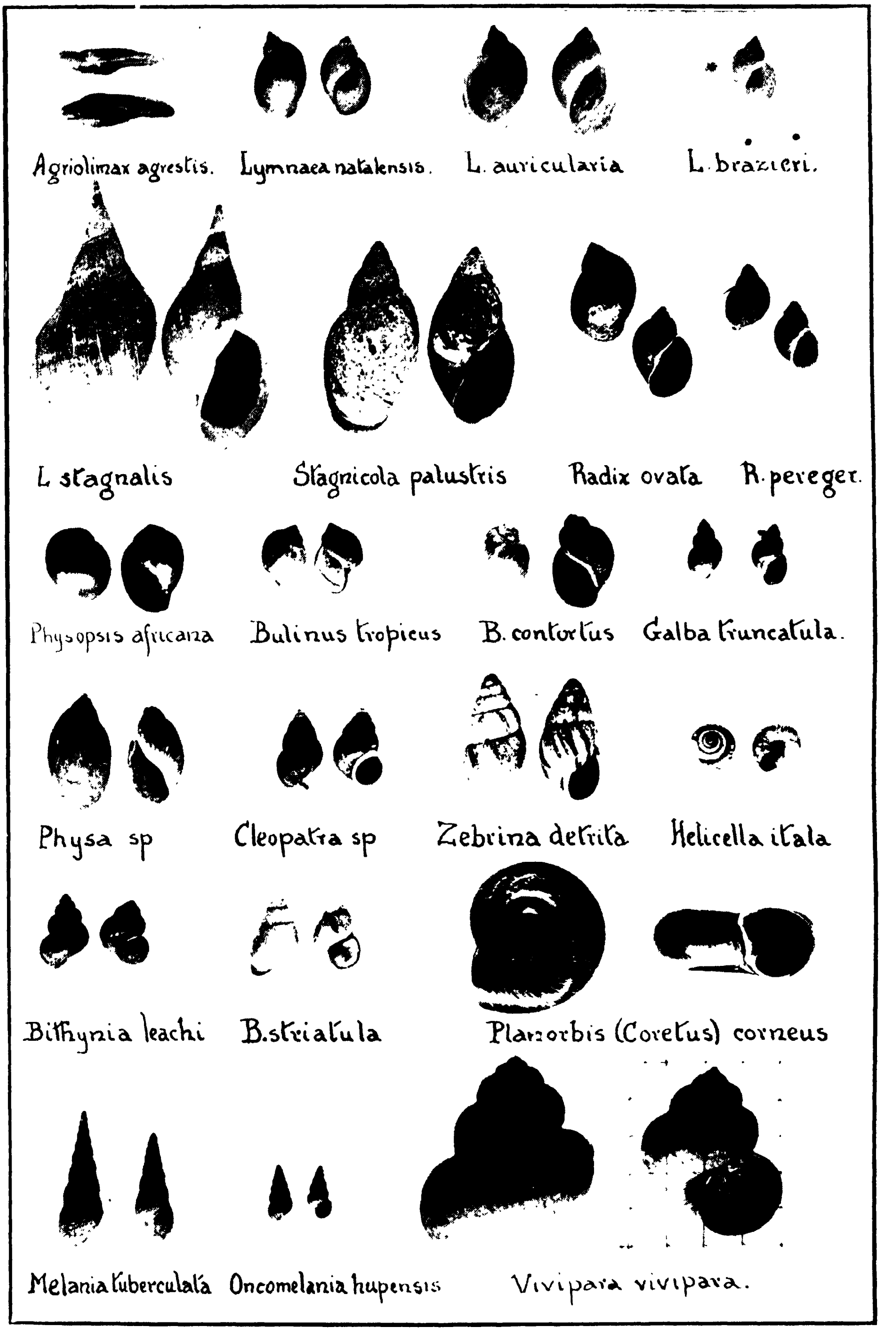

FIG. 13.—SHELLS OF VARIOUS IMPORTANT SNAIL INTERMEDIATE HOSTS: NATURAL SIZE. (ORIGINAL.)

[*To face page* 38.

Genus **Platynosomum** Looss, 1907

P. concinnum (Braun, 1901) (syn. *P. fastosum*) occurs in the liver of cats in the Malay States, British Guiana and Brazil, and has also been found in a wild cat. It measures 4-8 by 1·5-2·5 mm. It differs from *Dicrocœlium* mainly in being less lanceolate in shape, while the testes are horizontal in position. The eggs measure 34-50 by 20-35 μ.

Life-cycle unknown.

Pathogenicity.—Ware (1923) states that the lesions in the liver consist of dilatation, thickening and catarrh of the walls of the bile ducts and proliferation of the mucosa. According to Purvis* the liver is much enlarged and can be palpated through the abdomen. It is fragile and sometimes definitely yellow, but the bile ducts are usually not much thickened. A catarrh is present. The cats may be only thin, even when they harbour 200 to 300 flukes, but in heavy infections with 500 or more flukes the animal shows total loss of appetite and condition and may die.

Treatment unknown. Fuadin may be useful, as in opistorchiasis.

Prophylaxis unknown.

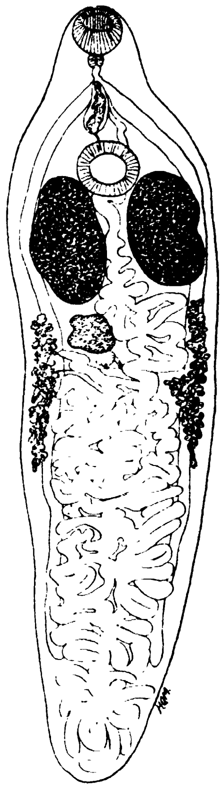

Fig. 14.—*Platynosomum concinnum*, Ventral View. (Original.)

Genus **Eurytrema** Looss, 1907

E. pancreaticum (Janson, 1889) is found in the pancreatic ducts and more rarely in the bile ducts and the duodenum of sheep, goat, cattle and buffalo in eastern Asia and Brazil. It measures 8-16 by 5-8·5 mm. The body is thick and armed with spines, which are often lost in the adult stage. The suckers are large, the oral being the larger of the two. The pharynx is small and the œsophagus short. The testes are horizontal, slightly posterior to the level of the ventral sucker. The genital pore opens just behind the bifurcation of the intestine. The cirrus-sac is tubular and reaches back past the anterior margin of the ventral sucker. The ovary is situated near the median line, behind the testes, and the uterus fills the posterior part of the body. The vitelline glands are follicular and situated as in *Dicrocœlium*. The excretory system has longitudinal branches running in the lateral fields alongside of the intestinal branches. The eggs measure 40-50 by 23-34 μ.

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* Private communication.

Several other species of this genus have been described from domestic and other ruminants, but it is not clear whether these are all distinct species. *E. ovis,* described by Tubangui in 1925 from sheep in the Philippines, occurs in the peri-rectal fat of that host. *E. cœlomaticum* (Giard and Billet, 1892) is common in the pancreatic ducts of Brazilian cattle.

Life-cycle unknown.

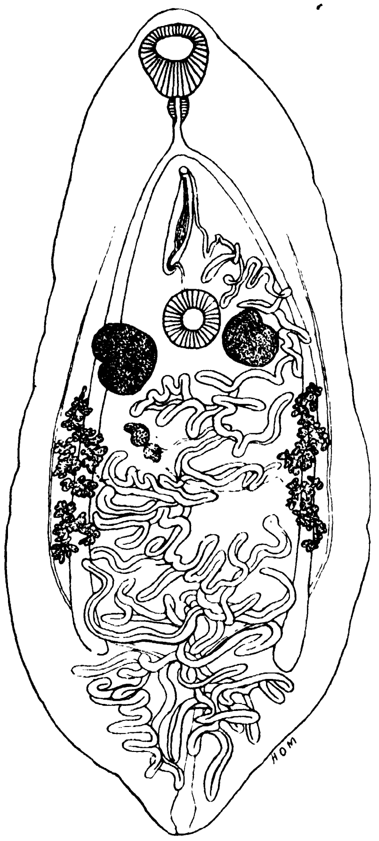

FIG. 15.—*Eurytrema pancreaticum,* VENTRAL VIEW. (ORIGINAL.)

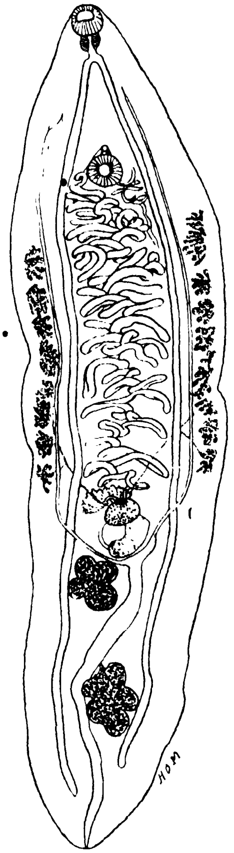

FIG. 16.—*Opistorchis tenuicollis,* VENTRAL VIEW. (ORIGINAL.)

Pathogenicity.—Burggraaf,* as well as Torres and Pinto,† describe the pathology of the condition. The parasites, as well as their accumulated eggs in the later stages, induce a chronic, proliferative inflammation of the walls of the glandular ducts, leading to their occlusion. Sometimes the duct walls become dilated and cystic. There are diffuse or focal agglomerations of lymphocytes, eosinophiles, foreign-body giant cells and other cells. Necrotic foci may be present. Glandular tissue and rarely also islands of Langerhans are destroyed by connective tissue spreading out from the ducts. Hypertrophy of glandular tissue indicates regenerative processes. Severely infected animals may be poor in condition, but no other symptoms have been definitely ascribed to these parasites.

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* *Tyd. v. Diergen.,* 60 (23): 1277-1282. 1933.

† *Mem. Inst. Osw. Cruz.,* 31 (4): 731-746. 1936.

Treatment and Prophylaxis unknown.

Family OPISTORCHIIDÆ

Small to medium-sized flukes with a usually much flattened and translucent body which is narrow anteriorly. The suckers are weak and not far apart. A pharynx and an œsophagus are present and the intestinal cæca reach near to the posterior extremity. The excretory bladder has a long stem and short branches. The genital pore opens just anterior to the ventral sucker. A cirrus-sac is absent, and the tubular seminal vesicle is coiled. The testes lie in the posterior part of the body; they are situated diagonally and are spherical or lobed. The ovary is not far anterior to the testes.

Laurer's canal and a large receptaculum seminis are present. The vitelline glands are moderately developed and lie in the lateral fields. The uterine coils usually do not extend behind the ovary. Eggs numerous and light brown. Parasites in the gall-bladder and bile ducts of reptiles, birds and mammals.

Genus **Opistorchis** R. Blanchard, 1895

O. tenuicollis (Rud., 1819) (syn. *O. felineus*) occurs in the bile ducts, and more rarely in the intestine and the pancreatic ducts of dog, cat, fox, pig, Cetacea and man, and has been found in southern Asia, Europe and Canada. It measures 7-12 by 1·5-2·5 mm. and has a reddish colour when fresh. The cuticle is smooth. The œsophagus is short and the intestinal cæca extend almost to the posterior end. The testes are lobed and the excretory bladder passes between them. The prostate gland and cirrus are absent and there is a weak ejaculatory duct. The ovary is small and lies in the mid-line at the beginning of the posterior third of the body. The vitellaria occupy the middle thirds of the lateral fields; they consist of a series of transversely arranged follicles. The uterine coils do not extend behind the ovary. The eggs measure about 26 by 11μ; they are provided with an operculum which fits into a thickened rim of the shell and contain an asymmetrical miracimdui when laid.

Life-Cycle.—The first intermediate host is the snail *Bithynia leachi*, according to Vogel,* and the metacercariæ are found in several fish (*Leuciscus rutilus*, *Blicca björkna*, *Tinca tinca* and *Idus melanotis*), into which the cercariæ penetrate through the skin and encyst in the subcutaneous tissues, especially at the bases of the fins. Infection of the final host occurs through eating raw infected fish.

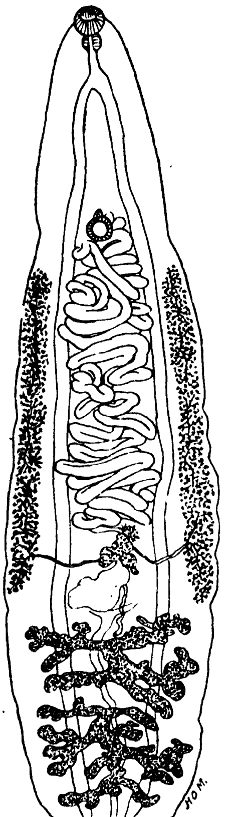

Fig. 17.—*Opistorchis sinensis*, Ventral View. (Original.)

Pathogenicity, Symptoms and Diagnosis.—Similar to the description given under *O. sinensis.* Several cases of carcinoma of the liver or pancreas due to this parasite have been described from cats and man.

Treatment.—For cats Erhardt† recommends Fuadin (neo-antimosan) in a dose of 0·4 c.c. per kilo subcutaneously, which was completely effective after one injection in his tests. Gentian violet in a single dose at the rate of 0·33 gm. per kilo was ineffective and 0·66 gm. per kilo removed the majority of the worms but caused marked inappetence and constipation.

Several other species of *Opistorchis* are known from man, carnivora and the pig, while *O. simulans* occurs in the duck.

O. sinensis (Cobbold, 1875) (syn. *Clonorchis sinensis*) occurs in the bile ducts and sometimes in the pancreatic ducts and the duodenum of dog, cat, pig, weasel and man. It may reach a size of 25 by 5 mm. It is flat, transparent, wide posteriorly and tapering anteriorly. The worm closely resembles *Opistorchis tenuicollis*, but the testes are tandem and much branched. The cuticle is spiny in the young but smooth in the adult. The eggs measure 25-31 by 14-18 μ and contain an asymmetrically arranged miracidium when laid. The operculum fits into a prominent rim of the shell, while the opposite pole frequently bears a small hook-like structure. This parasite is common in the south-eastern parts of Asia and Japan.

Life-Cycle.—The eggs normally hatch only after they have been swallowed by a suitable mollusc (*Parafossalurus striatulus*, *Bithynia* spp., *Melania hongkongiensis*, and probably others), in which the miracidium develops into a sporocyst which produces rediæ and these in turn cercariæ. The latter have fairly long tails and elongate bodies with pigmented eye-spots. After breaking out of the snail the cercaria swims about, and on meeting a suitable fish it penetrates partly or completely into the tissues and becomes encysted, with loss of the tail. Infection of the final host occurs through eating raw infected fish. A large number of fresh-water fish are known to act as secondary intermediate hosts. In some the metacercariæ are found only under the scales and animals which are fed with scales and offal of such fish become infected, while humans who eat the rest of the fish do not. The metacercariæ are liberated in the duodenum of the final host and reach the liver only via the bile duct. Eggs are passed from the sixteenth day after infection.

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* *Arch. f. Schiffs- u. Tropenhyg.*, 36 (10): 558-561. 1932.

† *Ibid.*, 36 (1): 22-31. 1932.

Pathogenesis.[*]—The worms live in the narrow proximal parts of the bile ducts. They suck blood, cause a catarrhal cholecystitis with desquamation of the epithelium, and may in rare cases bring about bile stasis by blocking up the passages, resulting in jaundice. Papillomatous or even adenomatous proliferation of the epithelium of the bile ducts takes place, together with cirrhosis of the surrounding liver tissue, and this frequently leads to the formation of pockets or cysts enclosing eggs and even worms. A toxic action is also believed to be present, since similar proliferative and cirrhotic lesions are found in connection with the small bile ducts which the flukes cannot reach.

Symptoms are not seen except in fairly heavy infections. The symptoms in man consist of diarrhœa, followed in severer cases by icterus, ascites and other symptoms, resulting from cirrhosis of the liver and derangement of the portal circulation. The blood presents no important changes.

Diagnosis must be confirmed by finding the eggs in the fæces, differentiating them from eggs of other flukes, especially the *Heterophyidæ*, which, however, contain a symmetrically arranged embryo.

Treatment.—For human cases Faust[†] recommends sodium antimony tartrate or gentian violet, which both reduce the infection considerably, but do not usually effect a complete cure. For cats Faust and Ke-fang[‡] recommend gentian violet orally, giving 330 mg. per kilo at each of four half-weekly treatments. Worms that are pocketed off are not affected, and a complete cure can therefore not be expected in such chronic cases. Ross[§] states that massive doses of carbon tetrachloride (1 c.c. per kilo in repeated doses) produce in dogs a decrease of egg-production, which is largely due to the destruction of the parasites. In view of the findings of Erhardt in connection with *Opistorchis tenuicollis*, Fuadin might be tried.

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[*] *Arch. f. Schiffs- u. Tropenhyg.*, 41 (7): 481-505. 1937.

[†] *Amer. Journ. Hyg.*, Monogr. Ser. No. 8. 1927.

[‡] *Arch. f. Schiffs- u. Tropenhyg.*, 30: 383-391. 1926.

[§] *Jap. Journ. Exper. Med.*, 8 (2): 71-78. 1930.

Prophylaxis should take the form of thorough cooking of all fish used as food. This should stop the infection to a great extent, but further measures to eradicate the snail intermediate hosts (which are operculate) and to prevent their infection from human excreta ought also to be considered. Faust recommends treatment of night-soil with ammonium sulphate to kill the fluke eggs.

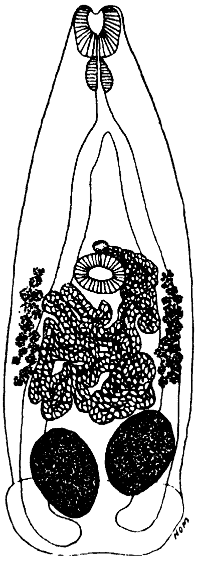

FIG. 18.—*Pseudamphistomum truncatum*, VENTRAL VIEW. (ORIGINAL.)

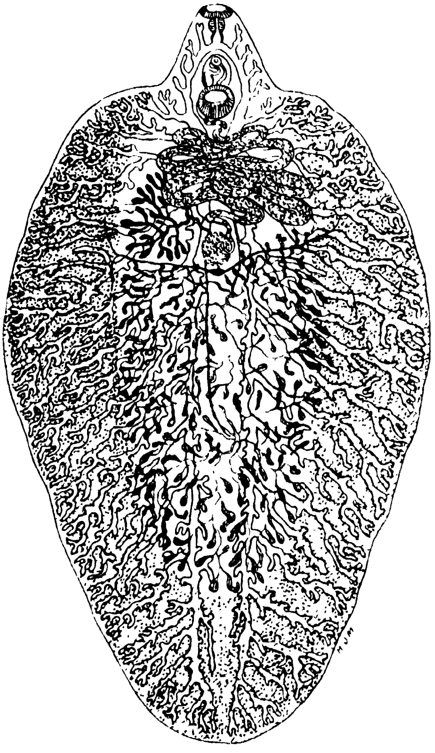

FIG. 19.—*Fasciola hepatica*, VENTRAL VIEW. (ORIGINAL.)

Genus Pseudamphistomum Lühe, 1908

P. truncatum (Rudolphi, 1819) occurs in the bile ducts of the dog, cat, fox, glutton, seal and sometimes man in Europe and India. It measures 2-2·25 by 0·6-0·8 mm. The body is truncate posteriorly, and the cuticle is spiny. The posterior ends of the intestinal cæca bend inwards around the testes, which are spherical and almost horizontal. The uterus extends mainly between the testes and the ventral sucker, which is situated near to the middle of the body. The eggs measure 29 by 11 μ.

Life-Cycle.—The first intermediate host is unknown, but is probably a mollusc. Schuurmans-Stekhoven found the metacercariæ in the fresh-water fish *Leuciscus rutilus*, *Scardinius erythrophthalmus*, *Abramis brama* and *Blicca björkna.*

Pathogenicity.—Not well known. Apparently the fluke is not very pathogenic.

Family FASCIOLIDÆ

These are large flukes with a broad, leaf-shaped body and usually a spiny cuticle. The ventral sucker is close to the anterior. A pharynx and a short œsophagus are present and the intestinal cæca are commonly much branched, especially laterally. The excretory bladder is also much branched. The genital pore is median, directly anterior to the ventral sucker. Testes tandem, lobed or branched. Vitellaria strongly developed, filling the lateral fields and extending medially as well. Receptaculum seminis absent. The eggs have thin shells and are operculate. Parasites in the bile ducts and intestines of mammals, especially ungulates.

Genus **Fasciola** Linnæus, 1758

F. hepatica Linnæus, 1758, occurs in the bile ducts of sheep, goat, cattle, other ruminants, pig, hare, rabbit, beaver, coypu, elephant, horse, dog, cat, kangaroo and man. In the unusual hosts, like man and horse, the fluke may be found in the lungs, under the skin or in other situations. The parasite is cosmopolitan in its distribution, and is the cause of liver-fluke disease, " liver rot " or fascioliasis, especially in sheep and cattle.

The parasite reaches a size of 30 by 13 mm., and is leaf-shaped, broader anteriorly than posteriorly, with an anterior cone-shaped projection which is followed by a pair of broad "shoulders." It is greyish-brown in colour, changing to grey when preserved. The ventral sucker is situated at the level of the "shoulders," and is about as large as the oral. The cuticle is armed with sharp spines. The intestinal cæca have numerous branches and extend far back. The testes are much branched, filling the median field in about the second and third quarters of the body. There is a well-developed cirrus, and the cirrus-sac also encloses the prostate and seminal vesicle. The ovary is situated to the right of the middle, anterior to the testes, and is branched. The vitelline glands consist of fine follicles filling the lateral fields and the transverse vitelline duct bears a yolk reservoir. The uterus lies anterior to the testes. The eggs measure 130-150 by 63-90 μ, and the miracidium develops only after the eggs have been laid.

Life-Cycle.—The eggs enter the duodenum with the bile and leave the host in the fæces. The rate of development and the hatching of the eggs depend greatly on the temperature. At 26° C. the eggs will hatch in about 9 days; the period is prolonged as the temperature decreases, and at 10° C. development is arrested, but the eggs may remain viable for a long time and hatch when the conditions become favourable. The eggs apparently do not require much oxygen, as they will develop even under fairly deep water. The miracidium is broad anteriorly, with a small papilliform protrusion. Its cuticle is ciliated and it has a pair of eye-spots. For further development an intermediate host is required and the miracidium can live free only about 24 hours; or, at low temperatures, a few days. The intermediate hosts are different species of snails in different countries; for instance, in Europe *Galba truncatula* and *Stagnicola palustris*; in America *Galba bulimoides*, *G. bulimoides techella*, *G. ferruginea*, *G. cubensis*, *Fossaria modicella*, *Limnæa traskii* and *Pseudosuccinea columella*; in the Philippines *Limnæa philippensis*, *L. swinhœi* and *Amphipepla cumingiana*; in Hawaii *Fossaria ollula*; in India *L. acuminata*; in Cuba *Physa cubensis*; in the Argentine *L. viatrix*; in Japan *L. pervia* and *L. japonica*; in New Zealand *Myxas ampulla*; in Australia *L. brazieri*; and in South Africa *L. natalensis* and *G. truncatula*, while *Physopsis africana* and *Bulinus tropicus* have also been incriminated.

The miracidium penetrates actively into the snail, casting off its ciliate covering, and develops into the sporocyst, which reaches a length of over 1 mm. Each sporocyst gives rise to 5-8 rediæ which, when fully developed, are 1-3 mm. long. They are characterised by a circular thickening behind the level of the pharynx and a pair of blunt processes at the beginning of the posterior quarter. Daughter rediæ may develop under unfavourable conditions, but the next normal generation is one of cercariæ. These leave the snail in 4½ to 7 weeks from the time of infection. They have a body 0·25-0·35 mm. long, a tail of twice that length, no eye-spots, and the dark, granular, cystogenous glands are conspicuous in the lateral parts of the body. Within a few minutes to 2 hours the cercariæ settle on blades of grass or other plants just below water-level and, after casting off the tail, secrete a covering from the cystogenous glands. A small number may encyst at the surface of the water and sink to the bottom. The cercariæ are now infective. They are swallowed by the final host with the plants on which they are encysted, or animals, like cattle that walk into the water to drink, may stir up the cercariæ lying at the bottom and swallow them.

The eggs, the young stages in the snails and the cercariæ may survive the winter and carry on the infection to the next season. It seems, however, that the infection in snails often dies out during the winter.

The cercariæ are able to live on dry hay for a few weeks (Nöller), but if the hay is not properly dried it may remain infective for a year or more, according to Marek and Rajcevic. In this way animals stabled in winter and fed on hay from infected pastures may contract the disease.

After having been ingested by the final host, the cercaria escapes from its cyst in the duodenum and burrows into the intestinal wall. Some of the young flukes may reach the liver via the bloodstream or by crawling up the bile duct, but the usual route is through the peritoneal cavity, after penetration of the intestinal wall. The parasites migrating through the peritoneal cavity attach themselves here and there to suck blood and eventually, after about a week, enter the liver by penetrating through the capsule. Then they grow and wander in the liver parenchyma for about a month or more, eventually reaching the bile ducts, in which they become mature in 2 to 3 months from the time of infection. Some of the young flukes that enter the bloodstream may become lodged in unusual sites and may even infect the fœtus in pregnant animals.

Pathogenesis.—No appreciable damage is done during passage through the intestinal wall and the peritoneal cavity, although small hæmorrhagic foci may be seen on the peritoneum where the worms attach themselves temporarily. The young flukes wandering in the liver parenchyma destroy the latter, leaving hæmorrhagic tracks where they go. As they grow the amount of destruction increases, causing important lesions in heavy infections. Acute massive infections may cause rupture of the liver capsule and hæmorrhage into the peritoneal cavity, or hæmorrhage may occur via the bile ducts into the intestine. In necrotic foci of destroyed liver tissue a strain of *Clostridium œdematiens* may develop and produce toxins which give rise to the disease known as " black disease " in Australia. The adult flukes in the bile ducts feed on liver tissue and blood and possibly also on the contents of the bile ducts. It has been shown that they produce a hæmolytic toxin. Also the normal metabolic wastes of the worms may be absorbed by the host and could be harmful. The cuticular spines of the parasites irritate the mucosa of the bile ducts, causing a chronic cholangitis and cirrhosis extending into the parenchyma from the ducts. On account of their large size the worms block the ducts. The resulting bile stasis may result in jaundice and, together with the epithelium desquamated by the worms, predisposes to the formation of gall-stones, the epithelial debris acting as nuclei on which the stones are formed.

Symptoms.—In acute cases, which are rare, the animal dies suddenly; blood-stained froth appears at the nostrils and blood is discharged from the anus, as in a case of anthrax. In the ordinary cases the first symptoms are seen at a time when the young worms, burrowing through the liver parenchyma, have reached a fair size. The sheep shows a temperature and is generally off colour. This is followed by an increasing anæmia. At first the sheep shows a tendency to fatten, which may be due to an increased flow of bile, resulting in better assimilation of fats, or to a decrease of fat combustion in the body as a result of the anæmia. At this time there is a marked muscular weakness which is observed when the animals are caught or driven. Soon the appetite diminishes, the mucous membranes become pale and œdemas develop, the latter being more conspicuous in some breeds than others and show especially in the intermandibular space, hence the name "bottle-jaw." The skin becomes dry and doughy to the touch; the wool is dry and brittle, falling out in patches. The debility, emaciation and general depression increase, and there may occasionally be diarrhœa or constipation and slight fever. At this stage or even earlier death may occur. The flukes usually live about 9 months in the sheep and then die and pass out through the intestine, but some may live up to 5 years. If the animals recover the symptoms gradually abate, but the wool later shows a "break" in the part grown during the illness, and the lesions in the liver are never completely repaired.

Complications in the form of other diseases, especially worm infections, are apt to occur on account of the lowered resistance of the body. It is generally observed that sheep rarely have only one worm infection at a time, since one paves the way for the other. The very important conclusion to be drawn from this is, that sheep should be kept free from the most injurious worms and they will be able to resist the others themselves.

In the case of cattle, the most characteristic symptoms are digestive disturbances. Constipation is marked and the fæces are passed with difficulty, being hard and brittle. Diarrhœa is seen only in the extreme stages. Emaciation increases rapidly, while dullness and weakness soon lead to prostration, especially in calves. In other animals anæmia, weakness and emaciation are the most prominent symptoms.

Post-mortem findings are mainly anæmia, cachexia, ascites, hydrothorax and hydropericard, fatty degeneration and cirrhosis of the liver, with thickened bile ducts containing the parasites and frequently gallstones. The left lobe of the liver is usually more affected than the right. In acute cases the liver is much congested and enlarged and shows numerous small, dark red areas, about 3 mm. in diameter, on its surface and in sections; the gall-bladder and the intestines contain blood; numerous young flukes are present. In cattle the walls of the bile ducts become calcified and may eventually be so hard that they cannot be cut through with a knife. Fibrinous peritonitis caused by the migrating young parasites and hæmorrhagic foci in the lungs have been described in cattle. The parasites may be found in unusual sites such as cysts in the lungs and other organs, and even under the skin or in the intestine.

Diagnosis is confirmed by finding the eggs in the fæces. They must be distinguished from the eggs of other flukes, especially paramphistomes. The *Fasciola* egg has a yellow shell with an indistinct operculum, and the embryonic cells are also rather indistinct. The paramphistome eggs as a rule have transparent shells and distinct opercula; their embryonic cells are clear and there is frequently a small knob at the posterior pole, while the eggs themselves are often larger than those of the liver-fluke.

Treatment.—For sheep pure carbon tetrachloride is the commonly used drug. The animals need not be starved nor kept from water, but they should receive no food which contains much protein or fat. Carbohydrates, on the other hand, appear to have a favourable influence. It is desirable to keep the animals on the pasture or hay ration to which they have been accustomed prior to dosing, providing extra carbohydrates and a lick of sterilised bonemeal where there is a deficiency of calcium. The sheep should not be dosed in hot weather and should be handled quietly. A dose of 1 c.c. is sufficient. It may be given pure in capsule, but is more satisfactorily administered by means of a syringe into the mouth, against the cheek on one side. In the latter case the drug is diluted with about 4 c.c. of a suitable fluid. The most commonly used vehicle is liquid paraffin, which mixes with the drug. Skimmed milk may also be used, but in that case each dose has to be measured off separately or the mixture must be constantly and vigorously shaken as the drug does not mix with milk.

The young flukes in the liver parenchyma are not killed, hence the treatment of sheep recently removed from an infected pasture must be repeated after about 4 to 6 weeks.

Male-fern preparations were formerly used, but are now rarely employed. For the treatment of cattle carbon tetrachloride is satisfactory if the precautionary measures are strictly observed, since the drug is more toxic for them than for sheep. The dose is 1-4 c.c. according to age and size. Alicata* recommends for cattle 10 gm. hexachlorethane and 1·75 gm. kamala extract per 70 pounds live weight, given in two doses over 2 to 3 days. This is very effective and better than either drug alone. Hexachlorethane produces colic in large doses; kamala causes diarrhœa and loss of appetite. For the copypu Sprehn recommends tetrachlorethylene, 0·3 c.c. per kilo bodyweight. This drug is not very effective in the case of sheep and cattle.

Besides medicinal treatment the animals should receive nourishing food, shelter against adverse weather conditions and a tonic lick containing a small quantity of iron sulphate.

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* *Amer. Journ. Vet. Res.*, 2 (3): 152-164. 1941.

Carbon tetrachloride (CCl_4) was introduced as an anthelmintic by Hall in America in 1921 for hookworms in dogs. It soon became one of the most important drugs against blood-sucking worms, and has been widely used for human hookworms. The drug is well tolerated by animals with a short intestine like birds and dogs and also by horses, but is more dangerous for ruminants and rather toxic for cattle. It tends to produce a central necrosis and fatty changes in the liver. The chemical changes which accompany carbon tetrachloride poisoning are of a complex nature, and their severity is not always commensurate with the extent of the visible liver lesions. They consist, apparently, of two different but related reactions: (i.) a retention in the blood of bile pigments which combine with the blood calcium and are excreted in this form, leading to a deficiency of ionised blood calcium and consequent hæmorrhages in serous and mucous membranes and sometimes tetanic convulsions; (ii.) a retention of guanidine in the blood, which interferes with the normal conversion of glycogen to blood sugar in the liver, leading to a marked hypoglycæmia and an increase of lactic acid—this is probably the most fatal factor. There is a definite antagonism between guanidine and calcium, since the latter opposes the effects of the former, and it is clear why the feeding of calcium and carbohydrates is desirable while proteins, which lead to increased guanidine formation, are contra-indicated. Diet cannot prevent the liver lesions, but can control their sequelæ to a great extent. Cases of poisoning can be treated by intravenous injection of small amounts of soluble calcium salts.

Affected animals may show nervous symptoms and gastrointestinal disturbances, while dogs frequently vomit. Later a comatose condition sets in and death may follow, as a rule 2 to 4 days after the administration of the drug. At autopsy hæmorrhages are usually seen under the skin and in the alimentary canal; the liver has a cooked appearance and icterus may be present.

The drug must be chemically pure. Contra-indications against its administration are in general (1) conditions in which the liver is highly taxed or pathologically much changed—not duc to liver-fluke infection—and perhaps in the late stages of pregnancy, although the drug is generally regarded to be safe for pregnant animals; (2) fatty foods which cause rapid absorption of the drug through the lymphatics: in such cases the drug reaches the systemic circulation without passing through the liver and acts on the brain as an anæsthetic; (3) fat animals in which the body fat binds the absorbed drug and retards its excretion; (4) calcium deficiency and also lactation, which causes a heavy drain on the body calcium; (5) in man alcoholism and gross ascaris infection; (6) in dogs distemper, mange and other debilitating conditions. In order to decrease the toxic effect of the drug, magnesium sulphate is frequently given immediately after it, especially in the case of dogs.

Tetrachlorethylene (C_2Cl_4) is very similar in anthelmintic efficacy to carbon tetrachloride, but produces no liver lesions and, being therefore much safer, is used for many blood-sucking worms, but is not effective against liver-fluke in sheep and cattle.

Prophylaxis.—Infected animals should be reguarly treated and wet pastures must be avoided and drained where this is practicable. Infected pastures should not be used for making hay.

An important measure is the destruction of snails, which can be done by the application of copper sulphate. A solution of one part in one to five million parts of water is usually sufficient to kill the snails and many of their eggs and is not injurious to stock, but may kill fish. The amount of copper sulphate required depends greatly on the amount of decayed organic matter in the water, and in some cases as much as 1 : 50,000 or more must be used, so that this method may become impracticable. The treatment has to be repeated after 2 to 3 months in order to kill any snails that have hatched from eggs which were not destroyed at the first treatment.

In the case of moist pastures the copper sulphate is best applied in the form of a 1-2 per cent. solution or as a powder mixed with 4-8 parts of sand, using from 10-30 kilos per hectare (about 10-30 lbs. per acre), according to the amount of surface water present. Stock should not be grazed on treated pastures until a rain has fallen. In the case of pools, a rough estimate of the volume of water has to be made and the required amount of copper sulphate is added after it has been dissolved in a small quantity of water. The difficulty of slowly running water, for instance a fountain on a hillside, can be overcome by placing at the origin of the stream a vessel containing a strong solution of copper sulphate dripping out through a hole at the bottom at a suitable rate or by suspending small bags of the chemical in the water until the snails have been killed.

F. gigantica Cobbold, 1885, is the common liver-fluke in many parts of Africa and occurs also in other parts of the world in domestic and wild ruminants. It is easily recognised on account of its large size, measuring 2·5-7·5 cm. in length and about 1·2 cm. in breadth. The "shoulders" are not as prominent as in *F. hepatica,* and the body is more transparent. The eggs measure 156-197 by 90-104 μ. The intermediate hosts in South Africa are *Limnæa natalensis* and *Physopsis africana,* in India *Limnœa acuminata,* in Hawaii *Fossaria ollula.* The life-cycle is essentially like that of *F. hepatica.* This parasite also causes fascioliasis.

Genus **Fascioloides** Ward, 1917

F. magna (Bassi, 1875) occurs in the liver, rarely the lungs, of cattle, horse, bison, yak, sheep and deer in North America and in cattle and deer in Europe. The worms are thick and flesh-coloured, measuring up to 100 by 26 mm. There is no distinct anterior cone-like projection. The eggs measure 109-168 by 75-96 μ.

Life-Cycle.—The eggs are passed in the one-celled stage and hatch after 4 weeks or longer. About 7 to 8 weeks are required for development in the intermediate hosts, which are the snails *Fossaria parva*, *F. modicella*, *F. modicella rustica*, *Galba bulimoides techella*, *Pseudosuccinea columella* and *Stagnicola palustris nuttalliana.* The parasite wanders about in the liver of the final host until it becomes encapsulated. It reaches maturity in sheep in about 5 months.

Pathogenicity.—According to Swales,* in cattle, bison and yak the parasites become enclosed in fibrous cysts before they reach maturity, hence their pathogenicity is comparatively low and these hosts probably never disseminate the infection. In deer encapsulation occurs later, the cyst is thin-walled and the intercepted bile ducts are not occluded, so that eggs may pass out through them. In sheep there is almost unchecked migration of the parasites and consequently great damage results, so that a sheep may be killed by two or three of these worms. At post-mortem the large bovidæ show an uneven liver surface and a characteristic black pigment in the liver, the hepatic glands and the surrounding peritoneum.

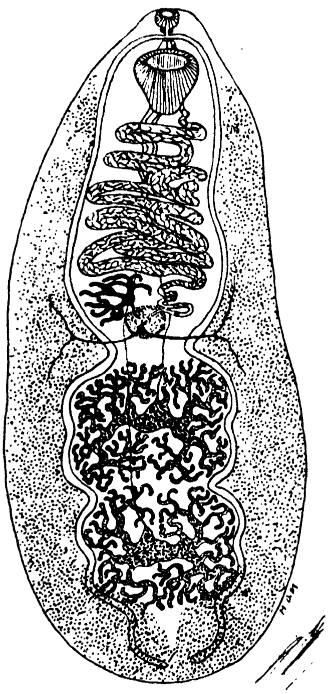

FIG. 20.—*Fasciolopsis buski*, VENTRAL VIEW. (ORIGINAL.)

Treatment.—Unknown.

Genus **Fasciolopsis** Looss, 1899

F. buski (Lankester, 1857) occurs in the small intestine of man and the pig in the south-eastern parts of Asia, particularly in China. Faust records also one case from a dog. It is a large, thick-set fluke, rather variable in size, but usually measuring about 30-50 by 12-15 mm. The shape is oval, slightly broader posteriorly than anteriorly. The ventral sucker is situated near the anterior extremity and is much larger than the oral. The cuticle bears spines which are frequently lost. A pharynx and a short œsophagus are present, followed by the unbranched intestinal cæca, which reach almost to the posterior end of the worm. The testes are tandem, branched and posterior in position. The cirrus-sac is long and tubular, opening anterior to the ventral sucker. The ovary is branched, lying to the right of the mid-line. The vitelline glands occupy the lateral fields. The eggs have thin shells with an operculum; they are brown in colour and measure 125-140 by 70-90 μ.

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* *Canad. J. Res.*, D. 14: 83-95. 1936.

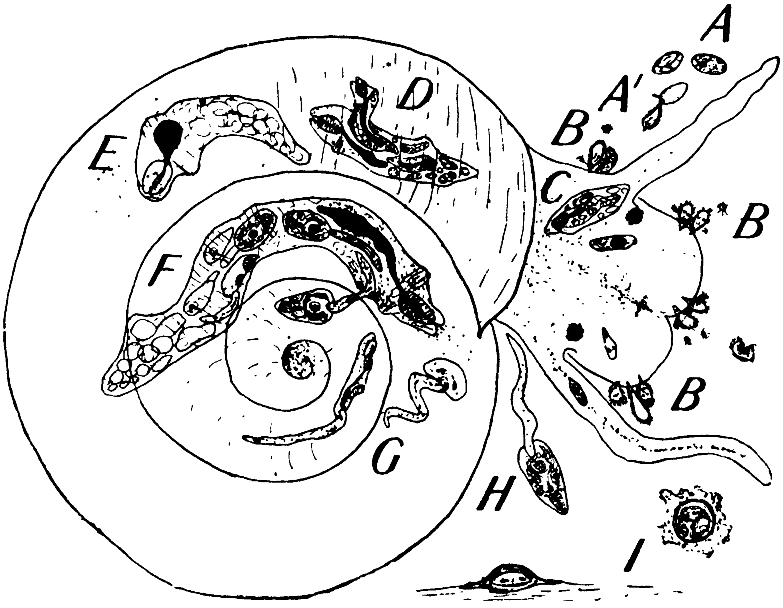

FIG. 21.—*Fasciolopsis buski.* DIAGRAM OF LIFE-CYCLE. (FROM BAYLIS, AFTER BARLOW.)

A, Egg; *A'*, miracidium escaping from egg; *B*, *B*, miracidia entering snail; *C*, sporocyst; *D*, redia; with daughter redia escaping; *E*, daughter redia; *F*, older daughter redia with cercariæ, *G*, cercaria; *H*, cercaria escaping from snail; *I*, encysted cercariæ.

Life-Cycle.—Similar to that of *Fasciola hepatica*, with flat, spiral-shelled snails as intermediate hosts (species of *Planorbis* and *Segmentina*). These snails feed on certain plants—the water calthrop, *Trapa natans* and *T. bicornis*, and the water chestnut, *Eliocharis tuberosa*—which are cultivated for food and are usually fertilised with human night-soil. The cercariæ encyst on the tubers or nuts of these plants, which are eaten raw by the Chinese. These and possibly also other plants may carry the infection to pigs.

Pathogenicity.—The parasite is chiefly of importance as a cause of disease in man. It attaches itself to the intestinal mucosa, causing a local inflammation or severer lesions in heavy infections, and produces abdominal pain, diarrhœa, œdema and ascites.

Treatment.—Carbon tetrachloride, at the usual dose rate of 0·3 c.c. per kilo and administered by stomach tube, will probably produce the best results.

Prophylaxis is mainly a matter of hygienic disposal of human night-soil and the fæces of pigs. The tubers and nuts of the plants mentioned should not be used as food without at least scalding them in boiling water.

Family ECHINOSTOMATIDÆ

More or less elongate flukes with a strong ventral sucker situated not far behind the oral. The latter is surrounded dorsally and laterally by a "head-collar" which bears a single or double row of large spines The cuticle is usually provided with scales or spines. The digestive tract consists of a pharynx, an œsophagus which nearly reaches the ventral sucker, and simple intestinal cæca which extend to the posterior extremity. The genital pore opens just anterior to the ventral sucker. The testes are entire or lobed, tandem or slightly diagonal, usually situated in the posterior half of the body. A cirrus-sac is present. The ovary is anterior to the testes, median or to the right, and a receptaculum seminis is absent. The vitellaria consist of coarse follicles lying in the lateral fields and frequently extending into the central field behind the testes. Uterus anterior to the ovary, containing relatively large eggs with thin shells. Parasites in the intestine and sometimes the bile ducts of birds and mammals. The life-history is similar to that of *Fasciola hepatica*, but the cercariæ frequently enter another snail, an amphibian or a fish, in which they encyst, and the final host becomes infected by ingesting the second intermediate host.

Genus **Echinostoma** Rudolphi, 1809

E. revolutum (Fröhlich, 1802) occurs in the rectum and cæca of the duck, goose, and other aquatic birds, the partridge and the fowl, as well as in man. It is 10-22 mm. long and up to 2·25 mm. broad. The head-collar bears 37 spines, of which 5 on either side form a group of "corner spines," and the cuticle is spiny in the anterior region. The testes are tandem, elongate, oval or slightly lobed, situated behind the middle with the ovary anterior to them. The cirrus-sac lies between the bifurcation of the intestine and the ventral sucker and may extend slightly beyond the anterior margin of the latter. The eggs measure 90-126 by 59-71 μ.

Life-Cycle.—The eggs hatch after developing under favourable conditions for about 3 weeks and the miracidium penetrates into an intermediate host, *Stagnicola palustris*, *Helisoma trivolvis*, *Physa gyrina*, *P. occidentalis*, *P. oculans*, *Planorbis tenuis*, *Limnæa stagnalis*, *L. attenuata*, *L.* (*Radix*) *peregra* or *L. swinhœi*. The cercariæ either encyst in the snail or escape and enter another of the same or a different species, for instance *Vivipara vivipara*, *Sphærium corneum*, *Fossaria* spp. or tadpoles. The final host becomes infected by ingesting these snails and the worms grow adult in 15-19 days.

Pathogenicity and Symptoms.—This parasite has generally been regarded as fairly harmless, but heavy infections may cause severe enteritis. See under *E. paraulum.*

Diagnosis is made by finding the eggs of the worms in the fæces of the host.

Treatment.—Carbon tetrachloride or tetrachlorethylene in doses of 1-2 c.c., administered with about 3 c.c. liquid paraffin by means of a syringe and 10 cm. of narrow rubber tubing which is pushed into the œsophagus, will probably give the best results.

Prophylaxis, as indicated by the life-cycle, should be directed towards extermination of the snails (see under *Fasciola hepatica*), and, where possible, the birds should have access only to ponds in which the snails can be properly controlled.

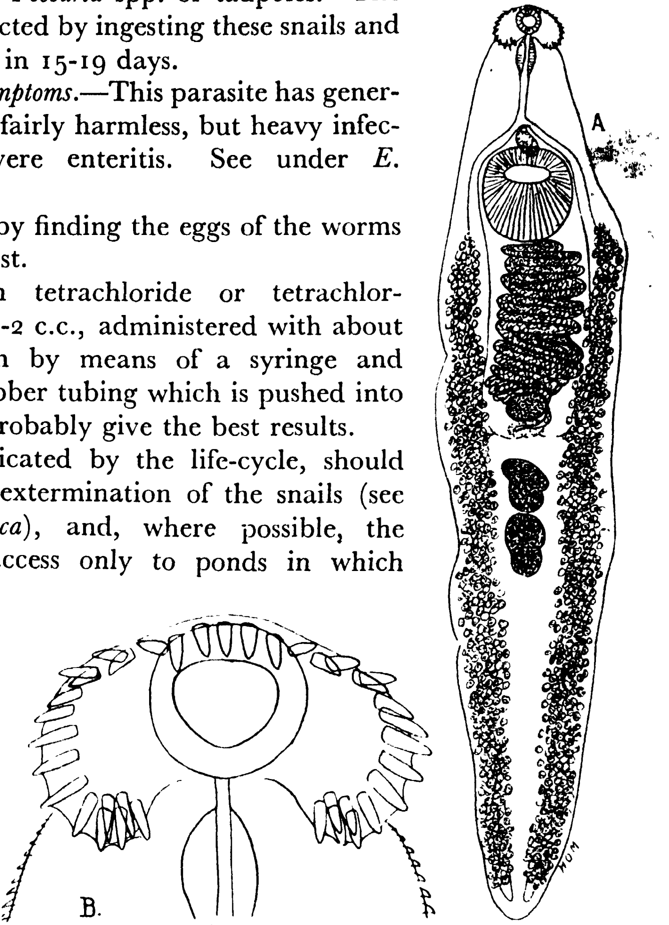

FIG 22.—*Echinostoma revolutum.* (ORIGINAL.)
A, Ventral view; B, ventral view of anterior end, showing the head-crown.

Genus **Echinoparyphium** Dietz, 1909.

E. paraulum (Dietz, 1909) (syn. *Echinostoma columbæ* Zunker, 1925) occurs in the small intestine of the duck, the pigeon and man. It measures 6·2-10·4 by 0·8-1·4 mm., and the cuticle bears spines almost to the posterior extremity; but these may be lost and their absence has in some cases caused much confusion. The head-collar, which is continuous across the ventral surface, bears 37 spines: 27 in a double dorso-lateral row and at either end 5 " corner spines." The oral sucker measures 0·25-0·3 mm. in diameter, and the ventral 0·72-0·88 mm.; the latter lies at the end of the first quarter of the body. There is a short prepharynx, a pharynx and an œsophagus; the latter is 0·4-0·6 mm. long. The testes are tandem and lie in the third quarter of the body; the anterior has frequently three and the posterior four lobes. The cirrus-sac may extend back to the middle of the ventral sucker. The ovary lies just anterior to the testes. The eggs measure about 100 by 70 μ.

Life-cycle unknown. The first intermediate host is probably a snail. Some authors suspect fish, and snails as the second intermediate host.

Pathogenicity and Symptoms.—Krause and Van Heelsbergen in Europe and Picard in Java have observed deaths in pigeons caused by this parasite. The birds show inappetence, thirst, diarrhœa, lassitude and progressive weakness. At post-mortem there is a slight atrophy of the breast muscles and catarrhal enteritis with much mucus, becoming hæmorrhagic behind the duodenum. The parasites are found chiefly in the middle portion of the intestine and may occur in large numbers.

Treatment.—Carbon tetrachloride should be tried as for *E. revolutum.*

Prophylaxis.—Extermination of the intermediate hosts is indicated, but is obviously a difficult matter in the case of birds like pigeons that fly and feed over a wide area.

E. recurvatum (v. Linstow, 1873) occurs in the small intestine, especially the duodenum, of the domestic duck, wild duck, fowls and pigeons. It is up to 4·5 mm. long and 0·5-0·8 mm. wide. The anterior end is curved ventrad and is armed with spines anterior to the ventral sucker. The head-crown has 45 spines, of which 4 are corner spines on either side. The ventral sucker is 0·32-0·36 mm. wide and situated at the first quarter of the body. Testes oval, tandem, not lobed and in contact with each other. The ovary is transversely oval and the uterus is short, containing 3-7 eggs, which measure 108-110 by 60-63 μ.

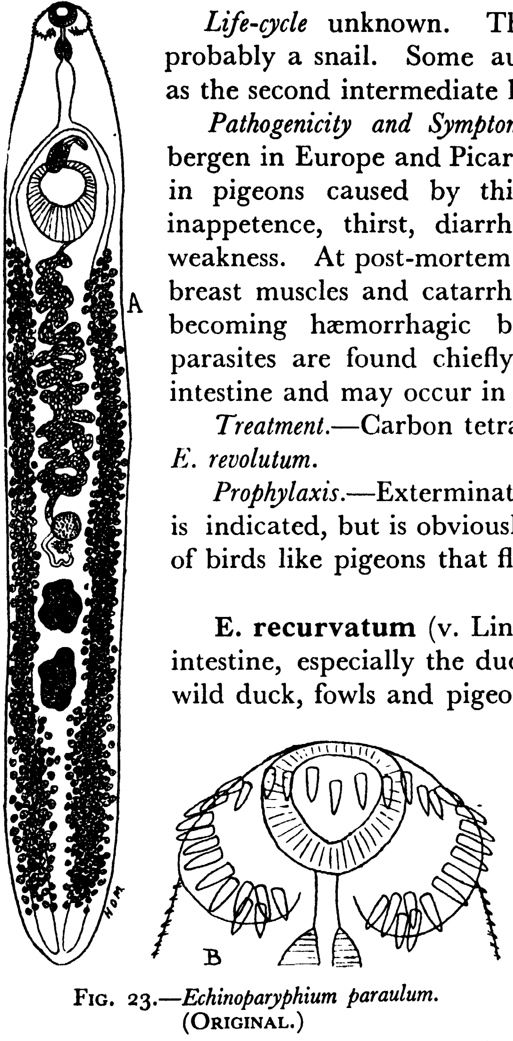

FIG. 23.—*Echinoparyphium paraulum.* (ORIGINAL.)

A, Ventral view; B, ventral view of anterior end, showing the head-crown.

Life-Cycle.—The first intermediate hosts are *Limnæa (Radix) ovata, L stagnalis, Planorbis planorbis, P. (Coretus) corneus* and *Vivipara vivipara*

The frog *Rana temporaria* and snails act as second intermediate hosts. The cercariæ encyst in the kidneys of the tadpoles and even adult frogs.

Pathogenicity and Symptoms.—Infected fowls show, according to Van Heelsbergen, emaciation, anæmia and sometimes weakness of the legs. At autopsy a marked enteritis with swelling of the mucosa and mucous content of the bowel are found.

Treatment.—Carbon tetrachloride or tetrachlorethylene is indicated, as in the case of *Echinostoma revolutum.*

Prophylaxis should be directed towards extermination of the snail intermediate hosts, and, where possible, the birds should be prevented from ingesting infected frogs. It is obvious that, although snails are important intermediate hosts of many trematodes, it is impossible to exterminate them everywhere without probably upsetting the water fauna, and the statement that the snails must be exterminated should be taken and applied with discretion.

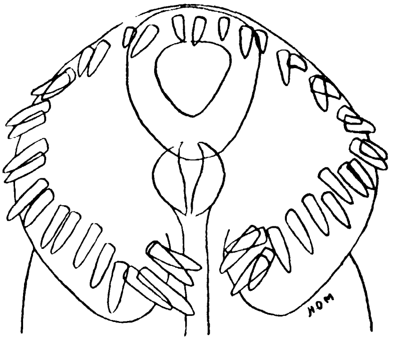

FIG. 24.—*Echinoparyphium recurvatum*, VENTRAL VIEW OF ANTERIOR END, SHOWING HEAD - CROWN. (ORIGINAL.)

Genus **Hypoderæum** Dietz, 1909

H. conoideum (Bloch, 1872) occurs in the posterior part of the small intestine of the duck, goose, swan, wild aquatic birds, fowl and pigeon. It is 5-12 mm. long and up to 2 mm. broad. The body is elongate and tapers posteriorly. The ventral sucker is relatively large and situated close to the anterior. The head-collar is weakly developed and bears 49 spines, of which 2 on either side form the " corner spines." The anterior part of the body is well armed with spines. The œsophagus is very short. Testes elongate, slightly lobed, tandem, behind the middle. The cirrus-sac is club-shaped, reaching back almost to the posterior margin of the ventral sucker. The eggs measure 95-108 by 61-68 μ.

Life-Cycle.—The first intermediate hosts are *Limnæa stagnalis*, *L.* (*Radix*) *peregra*, *L.* (*R.*) *ovata* and *Planorbis* (*Coretus*) *corneus.* Vevers has infected ducks by feeding infected *L.* (*R.*) *peregra*, showing that the cercariæ in the snail are infective. That they, however, usually appear to enter a second intermediate host which carries the infection to the final host is evident from the work of Nöller and Wagner,* who found

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* *Berl. Tierärztl. Wschr.*, 39 (44): 463-464. 1923.

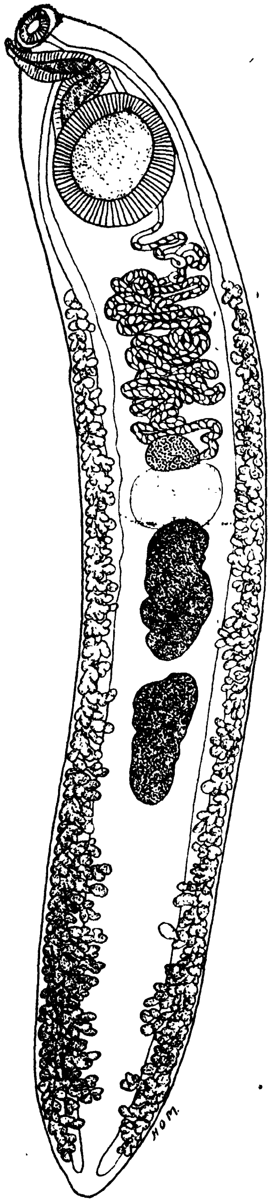

Fig. 25. — *Hypoderæum conoideum*, Ventral View. (Original.)

the cercariæ encysted in the kidneys of the tadpoles and young forms of the frog *Rana esculenta*.

Pathogenicity, Symptoms and Treatment.—As in the case of *Echinostoma revolutum*. Localised enteritis has been noted in infected ducks.

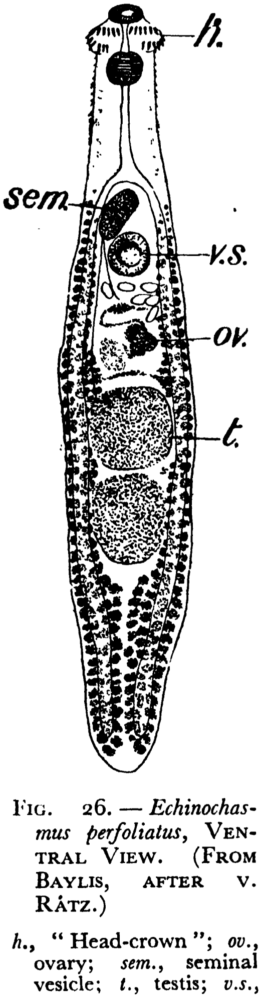

Fig. 26. — *Echinochasmus perfoliatus*, Ventral View. (From Baylis, after v. Rátz.)

h., "Head-crown"; *ov.*, ovary; *sem.*, seminal vesicle; *t.*, testis; *v.s.*, ventral sucker.

Genus **Echinochasmus** Dietz, 1909

E. perfoliatus (v. Rátz, 1908) occurs in the intestine of the dog, cat, fox and pig in Europe and Asia. It measures 2-4 by 0·4-1 mm. The head-crown bears 24 spines in a single row and the anterior region of the body is spiny. The testes are large, tandem and situated behind the middle. The ovary lies to the right, anterior to the testes. The cirrus-sac lies anterior to the ventral sucker. The vitellaria extend from in front of the ventral sucker to the posterior end of the body in the lateral fields, also extending inwards behind the testes. The eggs measure 85-105 by 60-75 μ, and have a yellow colour.

Life-Cycle. — The primary intermediate host is probably a snail and the metacercariæ have been found in a large number of fresh-water fish.

Pathogenicity.—This parasite causes severe enteritis.

Treatment.—Carbon tetrachloride or tetrachlorethylene is indicated.

Prevention.—Snails should be exterminated where this is possible, and raw fish should not be fed to the animal hosts.

Genus **Euparyphium** Dietz, 1909

E. melis (Schrank, 1788) occurs in the small intestine of the cat, fox, polecat, mink, pine marten, beech marten, badger, otter, weasel and hedgehog (*Erinaceus europæus*) in Europe. The worm is elongate, measuring 8-12 by 3-3·3 mm. The head-collar bears a dorsally continuous row of 27 spines. The whole ventral surface is covered with small spines, and dorsally they extend to the level of the pharynx. The ventral sucker lies in the first quarter of the body and the intestine bifurcates near its anterior border. The testes are median, tandem, entire or slightly lobed; the anterior one lies at the middle of the body. The ovary lies anterior to the testes to the right of the midline and the receptaculum seminis to the left. The cirrus-sac is well developed and extends dorsally to the ventral sucker. The cirrus is spiny. The vitellaria extend backwards from the level of the receptaculum seminis and almost meet behind the posterior testis. The uterus is short and the eggs measure 120-125 by 91-94 μ.

Life-Cycle.—According to Beaver the first intermediate host in the United States is the snail *Stagnicola emarginata angulata* and the metacercariæ are found in tadpoles.

Pathogenicity.—Sprehn states that heavy infections are seen in the polecat without producing symptoms. The mink, however, is very susceptible to the effects of these worms, which produce a hæmorrhagic enteritis in this host.

Treatment. — Carbon tetrachloride or male-fern extract is indicated.

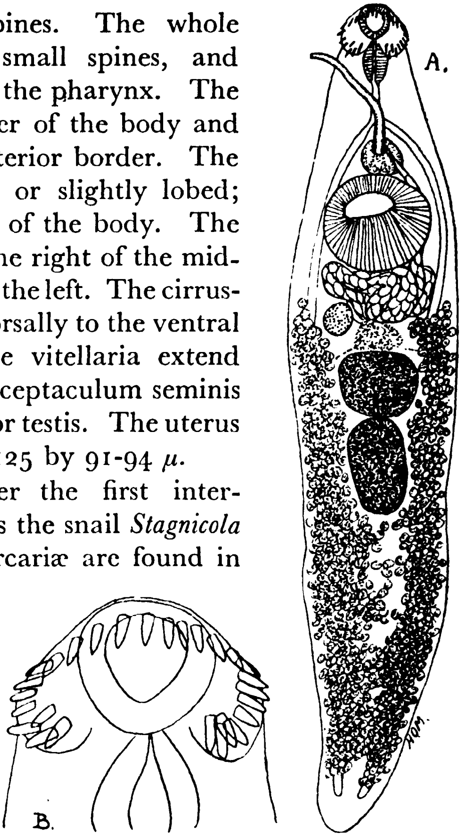

Fig. 27.—*Euparyphium melis.* (Original.) A, Ventral view; B, ventral view of anterior end, showing the head-crown.

Family HETEROPHYIDÆ

Small trematodes, usually not over 2 mm. long and wider posteriorly than anteriorly. The body is covered with scales, decreasing in numbers in the posterior region. The ventral sucker is usually situated near the middle of the body and may be weak or absent. A pharynx and a long œsophagus are present and the intestinal branches reach almost to the posterior end. The genital pore opens close to the ventral sucker and is frequently surrounded by a genital sucker. The testes are oval or slightly lobed, horizontal or diagonal, and situated near to the posterior end of the body. The seminal vesicle is well developed and there is no cirrus-sac. The ovary is oval or slightly lobed, anterior to the testes and median or to the right of the middle. The vitellaria are lateral and usually restricted to the posterior part. The uterus is not much coiled and contains relatively few eggs. Parasites in the intestines of mammals and birds. Where known the life-cycle includes two intermediate hosts—snails and fishes or frogs.

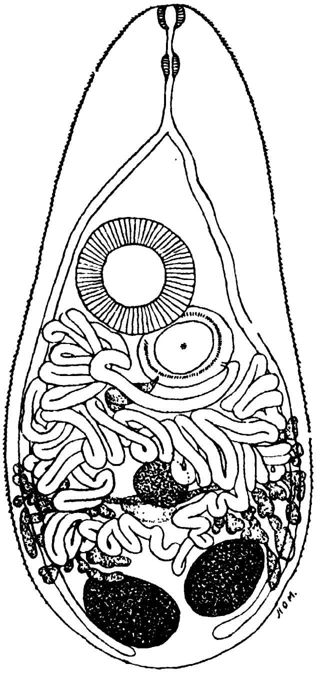

FIG. 28.—*Heterophyes heterophyes*, VENTRAL VIEW. (ORIGINAL.)

Genus Heterophyes Cobbold, 1866

H. heterophyes (v. Siebold, 1852) occurs in the small intestine of the dog, cat, fox and man in Egypt and eastern Asia. It measures 1-1·7 by 0·3-0·7 mm., and is wider posteriorly than anteriorly. The ventral sucker is situated immediately anterior to the middle and is 0·23 mm. wide. The genital sucker lies directly behind it and to one side and bears an incomplete circle of 70-80 small rods. The testes are oval and horizontal in position. The eggs have thick shells; they are light brown in colour, provided with an operculum which fits into a slightly thickened rim of the shell, and measure 28-30 by 15-17 μ.

Life-Cycle.—The first intermediate host is the snail *Pirenella conica*,* according to Khalil. The second intermediate host is a fish (*Mugil cephalus*, *M. japonicus*), in which the metacercaria is encysted. It bears a great resemblance to the adult fluke. Infection takes place through eating infected raw fish. In Egypt the fish is eaten salted as " fessikh "; the metacercariæ live up to 7 days in the salted fish. The adult starts laying eggs 9 days after infection.

Pathogenicity.—The flukes penetrate into the mucosa and may cause slight desquamation, but the pathogenicity of the parasites is so low that they are generally regarded as practically harmless. In severe human cases diarrhœa may develop; this is usually intermittent and sometimes hæmorrhagic.

Diagnosis is made by finding the eggs in the fæces. They have to be differentiated, especially from the eggs of *Opistorchis* and *Clonorchis*.

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* *Lancet*, 225 (5740): 537. 1933.

Treatment.—Male-fern extract, carbon tetrachloride, or tetrachlorethylene is recommended if treatment is necessary.

Prevention.—The infection can be prevented by using no raw fish as food, while salted fish should not be used within 10 days of salting.

Genus **Metagonimus** Katsurada, 1913

M. yokogawai (Katsurada, 1912) occurs in the small intestine of the dog, cat, pig, man and pelican in eastern Asia and the Balkans. Mice have been infected experimentally. The parasite measures 1-2·5 by 0·4-0·7 mm., and is wider posteriorly than anteriorly. The cuticle is armed with spines over the whole body. The ventral sucker is situated to the right of the median line and the genital pore opens in a sinus immediately anterior to it. The sinus and the sucker are surrounded by an elevated muscular ring. The testes are slightly oblique in position. The ovary is median, and the vitelline glands are composed of coarse follicles lying in the posterior parts of the lateral fields. The eggs are very similar to those of *Heterophyes* and measure 27-30 by 15-17 μ.

Life-Cycle. — The first intermediate hosts are snails of the genus *Melania* and others. The second intermediate hosts are several species of fresh-water fish in which the cercariæ become encysted and which serve to transport the infection to the final host when eaten raw.

Pathogenicity, etc., as in the case of *Heterophyes*.

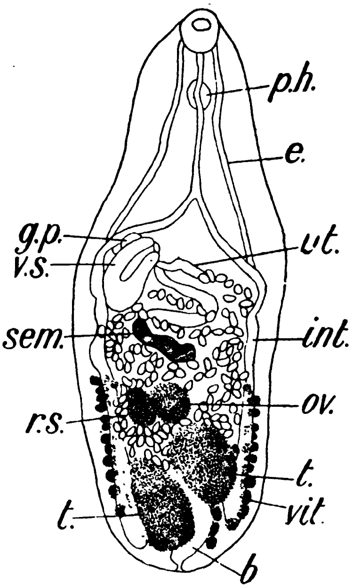

FIG. 29.—*Metagonimus yokogawai*, VENTRAL VIEW. (FROM BAYLIS, AFTER CIUREA.)

b., Excretory bladder; *e.*, excretory canal; *g.p.*, genital pore; *int.*, intestinal cæcum; *ov.*, ovary; *ph.*, pharynx; *r.s.*, receptaculum seminis; *sem.*, seminal vesicle; *t.*, *t.*, testes; *ut.*, uterus; *vit.*, vitellaria; *v.s.*, ventral sucker.

Genus **Euryhelmis** Poche, 1925

E. squamula (Rudolphi, 1819) occurs in the intestine of the fox, polecat, weasel and mink. The body is broad and flat, measuring about 0·6 by 1·45 mm. The oral sucker is anterior, and there are a pharynx and an œsophagus of median length. The intestinal cæca are more or less parallel to the margins of the body. The ventral sucker is situated near the middle, and is about half as large as the oral. The testes are lobed in the adult, horizontal and posterior in position.

The elongate cirrus-sac winds around the right side of the ventral sucker. The genital pore lies anterior to the ventral sucker. The ovary is lobed in the adult and lies anterior to the right testis, with a large receptaculum seminis in between. The uterus is coiled and lies mainly between the left testis and the ventral sucker. The vitellaria are well developed and extend along the course of the intestinal cæca. The eggs measure 28-32 by 12-14 μ.

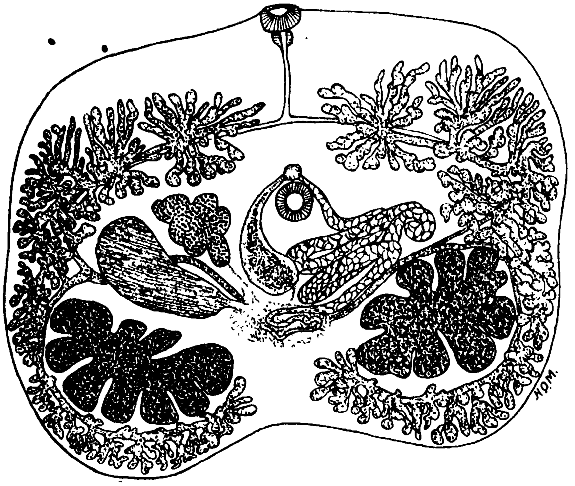

FIG. 30.—*Euryhelmis squamula*, VENTRAL VIEW. (ORIGINAL.)

Life-Cycle.—Not completely known. The metacercariæ are encysted in the skin of the frog *Rana temporaria.*

Pathogenicity. — Severe infections cause a fatal hæmorrhagic enteritis in the mink.

Treatment.—Male-fern extract or tetrachlorethylene is effective.

Prophylaxis.—The animals should be prevented from eating frogs.

Euryhelmis monorchis (Ameel, 1938) occurs in the mink. It has a single testis on the same side as the ovary and the male genital organs disappear later. Its first intermediate host is the snail *Pomatiopsis lapidaria*; second intermediate hosts are the frogs *Rana clamitans*, *R. pipiens* and *R. palustris*.

Family PLAGIORCHIDÆ

These are fairly large trematodes with thick bodies. The cuticle is usually covered with spines. A short prepharynx, a pharynx and an œsophagus are present, and the intestinal crura are of variable length. The genital pore is anterior to the ventral sucker, usually somewhat lateral, or it may lie next to the oral sucker. Testes entire or lobed, horizontal or tandem. A cirrus-sac is present. The ovary lies between the testes and the ventral sucker, to the right of the middle, and may be lobed. The vitellaria lie in the lateral fields. The uterus passes backwards and forwards between the testes. Eggs numerous with thin shells.

Genus **Prosthogonimus** Lühe, 1899

P. pellucidus (v. Linstow, 1873) (syn. *P. intercalandus*) occurs in the posterior part of the intestine of the fowl, duck, wild duck and curlew

(*Numenius arquatus*). It measures 8-9 by 4-5 mm., and is broad posteriorly. It has a pale reddish-yellow colour when fresh. The irregularly oval testes lie horizontal at the middle of the body. The genital pore is situated next to the oral sucker and the cirrus-sac is elongate, extending to near the ventral sucker. The ovary is much lobed and lies partly dorsal to the ventral sucker. The vitellaria extend from the level of the ventral sucker to the posterior ends of the testes. The eggs are operculate and bear a small spine at the opposite pole. They measure 26-32 by 10-15 μ.

*Life-Cycle.**—The first intermediate host is suspected to be a snail, but is not known. The second intermediate hosts are dragonflies, especially *Libellula quadrimaculata* and species of *Tetragoneuria*, which are infected by the cercariæ during the early part of their life when they develop in water. The birds become infected by ingesting the dragonflies.

Pathogenesis.—*P. pellucidus*, as well as other species of this genus, are considered to be the most pathogenic trematode parasites of poultry in Europe and America. Fowls are mainly affected, but occasionally also ducks. The worms live in the bursa fabricii, and in laying birds the movements of the oviduct apparently assist them to enter this organ. Here they cause marked irritation, resulting in an acute inflammation of the oviduct, the production of abnormal eggs and discharges of albumen from the cloaca. The irritated oviduct readily performs retroperistaltic movements, causing broken yolks, albumen, bacteria and parasite material to enter the peritoneal cavity, where they set up peritonitis, usually with fatal result.

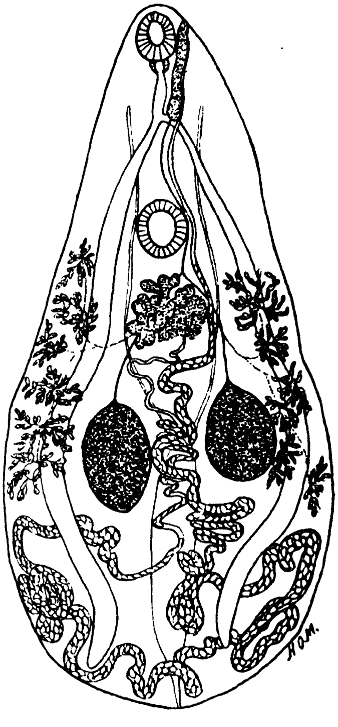

FIG. 31. — *Prosthogonimus pellucidus*, VENTRAL VIEW. (ORIGINAL.)

Symptoms.—The disease is usually seen in spring or early summer. At first the general health is not disturbed, but one notices that several hens begin to lay eggs with soft shells or without any shell at all. They may show a marked tendency to sit on the nest. There may be a discharge from the cloaca in the form of a milky fluid consisting chiefly of lime, which glues the feathers together around the anus. The irritated oviduct passes the eggs through so rapidly that no shell is deposited, although the lime-secreting glands act normally, and this secretion is then discharged separately. The birds become listless, the abdomen is pendulous and the legs are held widely apart in walking. Laying is suspended and the birds are obviously ill. The feathers around the cloaca are soiled with albumen, which is discharged and may contain yellowish-white strands and parasites. If peritonitis develops, the comb and wattles become cyanotic and the birds soon become prostrated and die. An " aseptic peritonitis " may also be seen, in which case the yolk in the peritoneal cavity becomes inspissated and may obstruct the intestinal peristalsis, causing death from toxæmia.

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* Macy found in North America that if the snail *Amnicola limosa porata* ingests the eggs of *Prosthogonimus macrorchis* the miracidia hatch and develop into sporocysts which directly produce cercariæ. The latter, after escaping from the snail, are drawn by breathing movements of dragonfly naiads into their anal openings and the metacercariæ become encysted in the muscles of the naiads.

Post-Mortem.—The oviduct shows varying degrees of inflammation according to the severity of the disease, from a catarrh to a croupous inflammation with a dirty, cheesy mass in the lumen. It may contain broken yolks and, frequently, large concrements of yolk and albumen. The parasites are not easily seen on the mucous membrane. In cases of peritonitis the abdominal cavity contains a dirty fluid and the organs are stuck together by a cheesy mass. Inspissated yolk may be present between the intestines. The serous membranes show a marked congestion and hæmorrhages may be present.

Diagnosis.—The eggs of the parasites can be found in large numbers in the discharges from the cloaca. In some cases the parasites may already have disappeared, but the disease continues. In such cases the worm eggs can frequently be found in the abdominal cavity at autopsy.

Treatment.—No satisfactory treatment is known for removing the parasites from the oviduct. In the early stages of the disease it will probably be advantageous to dose the birds with carbon tetrachloride, which may remove worms still present in the intestine and prevent them from entering the oviduct.

Prophylaxis.—As the first intermediate hosts are snails, the extermination of these, as well as preventing the animals from eating dragonflies as far as possible, is indicated.

Other species of *Prosthogonimus* occur in the bursa fabricii of birds such as fowls, ducks and geese. They may enter the oviduct and become included in the eggs, as for instance happens in the case of *P. ovatus*, which is 3-6 mm. long.

Sprehn records a small trematode, *Plagiorchis arcuatus*, as a cause of inflammation of the oviduct of fowls in Germany.

Family NOTOCOTYLIDÆ

These trematodes have no ventral sucker. The ventral surface of the body is provided with three or five rows of unicellular glands situated in groups. The cuticle is armed with fine spines anteriorly and ventrally. A pharynx is absent and the œsophagus is short, while the intestinal cæca extend to the posterior end of the body. The genital pore usually opens directly behind the oral sucker and the cirrus-sac is elongate. The testes are horizontally situated near the posterior end of the body and lateral to the intestinal cæca. The ovary lies between them. The vitelline glands occupy the lateral fields in the posterior part, anterior to the testes. The uterus forms more or less regular transverse coils extending from the ovary to the posterior end of the cirrus-sac. The eggs bear long filaments at both poles. Parasites in the intestine of aquatic birds and mammals.

Genus **Notocotylus** Diesing, 1839

N. attenuatus (Rudolphi, 1809) occurs in the cæca and rectum of the fowl, duck, goose and wild aquatic birds. It measures 2-5 by 0·6-1·5 mm., and is narrow anteriorly. There are three rows of ventral glands, 14-17 in the lateral rows, and 14-15 in the middle row. The vagina is half as long as the cirrus-sac. The eggs are small, 20 μ long, and bear a long filament at either pole.

Life-Cycle.—The intermediate hosts are the snails *Planorbis rotundatus*, *Limnæa palustris*, *L. limosa* and *Bulinus striatulus japonicus*.

Genus **Catatropis** Odhner, 1905

C. verrucosa (Fröhlich, 1789) occurs in the cæca of the fowl, duck, goose and wild aquatic birds. It measures 1-6 by 0·75-2 mm., and is reddish in colour. The body is rounded anteriorly and posteriorly. There are three ventral rows containing each 8-12 glands. The eggs measure 20 μ in length, not including the filaments.

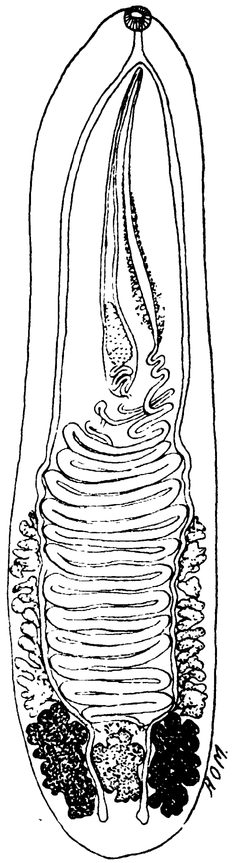

FIG. 32. — *Catatropis verrucosa*, VENTRAL VIEW. (ORIGINAL.)

Life-Cycle.—Szidat* has followed the development through the snail *Planorbis* (*Coretus*) *corneus*. The cercariæ have simple tails and three eye-spots. They leave the snail and encyst on water-plants, snails, etc., which may be ingested by the final host. The worms become sexually mature within a short time after infection.

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* *Arch. f. Geflügelk.*, 4 (3): 105-114. 1930.

Pathogenicity.—The *Notocotylidæ* are usually considered to be relatively harmless. Szidat, however, found that they attack the mucosa of the cæca and produce erosions.

Treatment.—The location of the worms in the cæca of the birds will make treatment a difficult matter. No remedy is known, but carbon tetrachloride might be tried.

Prophylaxis.—The birds should be kept away from suspected water and extermination of snails might be attempted.

Genus Cymbiforma

C. indica (Bhalerao, 1942) occurs in sheep, goats and cattle in India. The parasites live in all parts of the digestive tract behind the œsophagus, but particularly the duodenum. Heavy infections are frequent. They die and disintegrate rapidly after death of the host.

They are pear-shaped and concave ventrally, measuring 0·8-2·7 by 0·31-0·96 mm. The genital opening is to the left of the mid-line, a short distance anterior to the middle of the body. The ovary has four distinct lobes. The eggs measure 18-37 by 11-13 μ and carry filaments at the poles.

Family BRACHYLÆMIDÆ (*syn.* HARMOSTOMIDÆ)

More or less elongate trematodes with usually smooth bodies. A prepharynx, pharynx and œsophagus are present and the intestinal cæca extend to the posterior end of the body. The testes are posterior in position, tandem or slightly diagonal, and the ovary lies between them. The vitellaria are follicular and occupy the lateral fields. The genital pore is posterior, median or slightly lateral or even terminal or dorsal. The cirrus-sac contains a cirrus, but the seminal vesicle lies free. Parasite in the intestine of vertebrates.

Genus Brachylæmus Dujardin, 1843 (*syn.* Harmostomum)

B. commutatum (Diesing, 1858) occurs in the cæca of the fowl, pheasant, turkey, pigeon and guinea-fowl in southern Europe, North Africa and Indo-China. It measures 3·7-7·5 by 1-2 mm. The body is rounded anteriorly and tapers posteriorly. The ventral sucker lies within the anterior third of the body. The testes are irregularly rounded; the posterior one is median and the anterior one lies to the left of the mid-line, while the ovary lies to the right. The vitellaria consist of fine follicles extending in the lateral fields forwards from the level of the posterior testis. The uterus has coiled ascending and descending branches, and the genital pore is situated near the anterior border of the anterior testis in the mid-line. The eggs measure 27-32 by 13-18 μ.

Life-cycle unknown.

Pathogenicity.—The parasites may cause an inflammation of the cæca.

B. suis (Balozet, 1936) occurs in the small intestine of the pig in Tunis and sucks blood, but is apparently not very pathogenic. The intermediate hosts are land snails, especially *Xerophila* species. The eggs are light brown and measure 30-35 by 15-17 μ.

Family TROGLOTREMATIDÆ

These trematodes usually have a fleshy body, flattened or concave ventrally and convex dorsally, with a spiny cuticle. The suckers may be poorly developed and the ventral is sometimes absent. A pharynx and a short œsophagus are present and the intestinal cæca do not quite reach the posterior end. Genital pore median or slightly to the left, close to the ventral sucker when this is present. The testes are horizontal, at or behind the middle, elongate or deeply lobed. The cirrus-sac is usually absent. The ovary lies anterior to the right testis and is usually deeply lobed. The vitelline glands are strongly developed and almost fill the dorsal aspect of the body. Uterus and eggs variable. Parasites of carnivorous mammals and birds, usually in pairs in cysts in various parts of the body.

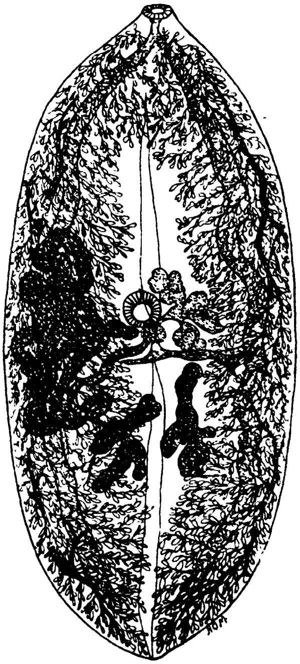

FIG. 33.—*Paragonimus westermanii*. DORSAL VIEW. (ORIGINAL.)

Fb

Genus Paragonimus Braun, 1899

P. westermanii (Kerbert, 1878), the "lung-fluke," occurs in the lungs and more rarely in the brain, spinal cord and other organs of the pig, dog, cat, goat, cattle, fox, pine marten, beech marten, mink, musk-rat, wild carnivores and man. The parasite is reddish-brown in colour and measures 7·5-16 by 4-6 mm. The cuticle is covered with spines. The ventral sucker is situated slightly anterior to the middle. The eggs are yellowish-brown in colour and measure 80-100 by 48-60 μ; they are provided with an operculum, and the shell is thickened at the opposite pole.

FIG. 34.—*Paragonimus kellicotti*, CUTICULAR SCALES. (ORIGINAL.)

Several distinct species of *Paragonimus* are recognised by some authors: *P. westermanii* originally found in the tiger, *P. ringeri* from man in China and Japan, and *P. kellicotti* found in the cat, pig and dog in the United

States, in the tiger in the Malay States and in the cat in South Africa. The main difference lies in the shape of the spines, those of *P. ringeri* being small and arranged in groups, those of *P. westermanii* are larger and have bifid points, while those of *P. kellicotti* are still larger and have a number of points each. Ameel* found cercariæ of *Paragonimus* in the snail *Pomatiopsis lapidaria* in the United States and raised the metacercariæ in crayfish. He points out differences which may be of specific significance between the cercariæ and metacercariæ of Asiatic and American lung-flukes.

Life-Cycle.—The eggs are laid in the cysts, in which the worms live and escape through connecting channels into the bronchi, or else when the cysts rupture. They are brought up from the lung with the mucus and may be found in the sputum, which has a characteristic rusty colour. Animals will usually swallow the mucus, so that the eggs will be found in the fæces. After development for 2 to 7 weeks (16 days under optimal conditions) the miracidium escapes and penetrates into a snail of the genus *Melania*, *Ampullaria luteostoma* or *Pomatiopsis lapidaria*, in which the usual further development takes place, including sporocysts, rediæ and cercariæ. The latter have an oval body and a very short tail. They measure 200-220 by 70-80 μ. The oral sucker is large and bears a stylet, which is surrounded by the openings of several glands. After escaping from the snail the cercariæ swim about in the water and, on meeting a suitable crab or crayfish, penetrate into it and encyst. In Japan and China the following crustacea are known as secondary intermediate hosts: *Astacus dauricus*, *A. japonicus*, *A. similis*, *Eriocheir japonicus*, *E. sinensis*, *Potamon dehaani*, *P. obtusipes*, *P. sinensis* and *Sesarma dehaani*; and in Venezuela: *Pseudotelphusa iturbei*. The final host becomes infected by eating the infected crustacea or through drinking water in which the metacercariæ occur, having escaped from these intermediate hosts. The latter method of infection is probably responsible for the occurrence of the parasite in hosts like tigers, etc. The metacercariæ escape from the crustacea when these are injured and may live in water for 3 weeks.

According to the researches of Yokogawa, the young fluke, after becoming liberated in the intestine, penetrates through the wall and wanders through the peritoneal cavity and diaphragm, entering the lungs from the pleural cavity. It arrives in the bronchioles, where the host forms a cyst wall around it, and grows adult. Young flukes introduced into the lungs do not remain there, but migrate through the body. The cysts in the lungs apparently develop from dilated small bronchioles. They are lined with stratified epithelium and are usually connected by fine channels with the bronchi, through which the eggs are discharged.

* *Journ. Parasitol.*, 18 (4): 264-268. 1932.

Pathogenicity and Symptoms.—The parasites in the lungs are not usually of great importance, but those lodged in the brain and other organs may cause trouble. In the lungs the parasitic cyst is surrounded by diffuse connective tissue which encroaches on the lung parenchyma. The cyst wall is infiltrated with leucocytes and giant cells. Eggs may be present in the lung tissue, where they cause small pseudotubercles to develop.

In animals the cyst usually contains two parasites, surrounded by a purulent fluid mixed with blood and the eggs. In lung infections there is a cough and the eggs may be found in the sputum in large numbers. Parasitic cysts in other parts of the body may work their way to a surface like the intestinal mucosa, the epithelium of the bile-ducts or the skin, where the eggs are discharged and ulcers form which heal with great difficulty.

Diagnosis of lung cases is readily made by finding the eggs in the sputum or fæces. In other cases diagnosis may be extremely difficult.

Treatment.—No satisfactory treatment is known. Tartar emetic is stated to give relief in human lung cases, but the parasites are apparently not killed. According to Yokogawa and Rao intramuscular injections of soluble prontosil and emetine hydrochloride are effective.

Prophylaxis.—Fresh-water crustacea should not be eaten raw and the extermination of snails should be considered.

Genus **Collyriclum** Ward 1917

C. faba (Bremser, 1831) occurs in subcutaneous cysts in the fowl and turkey as well as in several small wild birds like sparrows and starlings. It measures 3-5 by 4·5-5·5 mm. It is flattened ventrally and convex dorsally. The oral sucker is large. The genital pore opens directly anterior to the middle. The ovary has three main lobes and each is divided into several smaller lobes. The vitellaria are situated in the anterior half of the body and consist each of about seven large follicles. The eggs measure 19-21 by 9-11 μ.

Life-Cycle.—The first intermediate hosts are probably snails. Metacercariæ resembling the adults have been found in dragonflies. Only birds which have access to marshy places become infected.

Pathogenicity and Symptoms.—The parasites are found mainly around the cloacal opening and in heavier infections also along the abdomen and thorax. They are lodged in subcutaneous cysts, 4-6 mm. in diameter. Each cyst has a central opening and contains a pair of the worms, lying with their ventral surfaces apposed. The cysts also contain a black fluid and the eggs, which are discharged through the pore. The latter is, according to Marotel, the follicle of a feather. Heavy infections produce anæmia, emaciation and death.

Treatment.—The cysts should be opened and the worms extracted, followed by suitable treatment of the wound.

Prophylaxis.—The birds are to be kept from marshy places where they become infected.

Genus **Troglotrema** Odhner, 1914

T. acutum (Leuckart, 1842) occurs in the frontal and ethmoidal sinuses of the fox, mink and polecat in Europe. The parasites are whitish in colour and measure about 3·27 by 2·25 mm. The body is thick and rounded anteriorly and has a narrow, tail-like, posterior extremity. The ventral sucker is located just anterior to the middle and is as large as the oral. The testes are entire or slightly lobed and lie just behind the middle. The genital pore opens immediately behind the ventral sucker. The ovary is spherical and lies to the right of the mid-line close to the ventral sucker. The eggs measure about 80 by 50 μ.

Life-Cycle.—According to Sprehn, frogs act as secondary intermediate hosts.

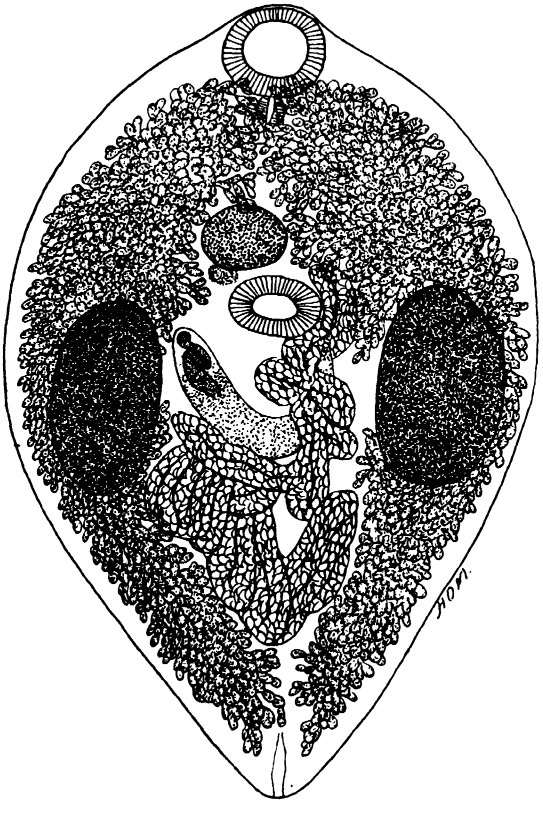

Fig. 35.—*Troglotrema acutum*, Ventral View. (Original.)

Pathogenicity.—The parasites may live in pairs in cysts or, particularly in the fox, they are found freely attached to the mucosa. In the mink and the polecat the parasites cause decalcification and atrophy of the bony walls of the sinuses and eventually perforation. The cysts in which the worms sometimes occur and which also contain their eggs may break open to the exterior or into the brain cavity.

Treatment unknown.

Prophylaxis.—The animals should be prevented from eating infected frogs.

T. salmincola (Chapin, 1926) (syn. *Nanophyetus salmincola*) is a small trematode, 0·5-1·1 mm. long, which occurs in the north-west Pacific area of the United States in the small intestine of the dog, coyote (*Canis lestes*), raccoon, mink and lynx (*Lynx fasciatus*), and has been experimentally transmitted to foxes and other carnivora as well as guinea-pigs and white rats. Witenberg* considers that *T. schikhobalowi* (Skrjabin and Podjapolska, 1931), which was found in man, is identical with *T. sal mincola*. The worms are white or cream in colour. The testes are oval and lie ventral and lateral to the posterior ends of the intestinal cæca, behind the middle of the body. There is a large cirrus-sac and the genital pore is situated a short distance behind the ventral sucker. The vitallaria are composed of large follicles and lie mainly laterally and dorsally. The ovary is spherical and situated behind and to the right of the ventral sucker. The eggs measure about 64-80 by 34-50 μ; they are yellowish-brown and have an indistinct operculum.

Life-Cycle.—The eggs are passed in the fæces of the host and hatch in 3 months or longer, depending on the temperature. The first intermediate host is *Goniobasis plicifera silicula*, a snail with an elongate spiral shell, about 4 cm. long. The cercariæ penetrate into fish of the salmon family (*Salmo* spp., *Oncorhynchus* spp., and *Salvelinus fontinalis*), encysting in the kidneys, muscles and other organs. The cysts are 0·17-0·255 mm. in diameter and remain viable in fish stored at temperatures above freezing-point for 3½ months, but are rapidly killed by freezing. Infection of the final host occurs when infected fish is eaten. The parasites grow adult in a short time; dogs pass eggs 5 days after infection.

Pathogenicity.—The flukes penetrate deeply into the mucosa of the duodenum or attach themselves to the mucosa in other parts of the small and large intestine, producing a superficial enteritis and necrosis and sometimes hæmorrhagic enteritis. The parasite is associated with the disease known as "salmon poisoning." It has been shown by Simms and his co-workers that this disease is secondary to the parasitic infection, and is possibly due to a virus transmitted by the flukes. The disease can be transferred from infected to susceptible dogs by injection of blood, even quantities as small as 0·1 c.c. being sufficient, while no spread occurs through contact only.

Symptoms.—Salmon poisoning occurs in *Canidæ* only (dogs, coyotes and foxes). The symptoms† develop 6 to 10 days after infection and the onset is very sudden, beginning with complete loss of appetite and a temperature of 39·7-41·1° C. (103·5-106° F.). The sensorium is depressed. After 3 days the temperature drops and may reach normal on the 6th to 8th day. A purulent discharge from the eyes and œdema of the eyelids are usually seen on the 3rd to 5th days. From about the 4th day onwards vomiting may be very pronounced, especially after drinking water, and the animals are then very thirsty but can retain little. Diarrhœa develops on the 5th or 6th day and is usually hæmorrhagic. When the temperature reaches normal the animal appears to recover, but this is transitory, as the temperature continues to drop and death takes place 24 to 48 hours later. The mortality in natural cases ranges from 50 to over 90 per cent.

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* *Journ. Parasitol.*, 18 (4): 258-263. 1932.

† *Journ. Amer. Vet. Med. Assn.*, 34 (1): 26-36. 1932.

Post-Mortem.—The main lesions are seen in the intestine in the form of an enteritis, sometimes hæmorrhagic, affecting chiefly the ileo-colic valve, the rectum and the lower part of the ileum. In some cases the duodenum is also involved. The parasites may be present in large numbers, but dogs have died after receiving only 100 metacercariæ.

Diagnosis.—The symptoms, especially the sudden onset, loss of appetite, vomiting, diarrhœa and the presence of the eggs in the fæces, allow a definite diagnosis to be made.

Treatment.—Several drugs have been tried without success, *e.g.* male-fern extract, areca nut, carbon tetrachloride, tetrachlorethylene and calomel. Shaw and Howarth report successful treatment with sulphanilamide when the symptoms appear after artificial infection. The dogs were immune thereafter.

Immunity.—Dogs that have recovered from an attack of the disease have a strong immunity and are refractive to infection with the parasite, but some flukes may develop in them without causing symptoms. No immunity is obtained by infecting the animals with a small number of worms. The simultaneous injection of virulent blood and serum of hyperimmune dogs produces a satisfactory immunity against the disease.

Prophylaxis.—No infected fish should be fed. If such fish is accidentally eaten apomorphine can be given, and it is stated to have prevented the disease when administered as long as 3 hours after infected fish had been eaten.

Family CYCLOCŒLIDÆ

These trematodes are medium-sized to large and flattened. The oral sucker is absent and there is usually also no ventral sucker. The mouth is anterior, there is a muscular pharynx and the intestinal cæca are simple or branched and are joined together posteriorly. The genital pore opens a short distance behind the mouth. The copulatory organs are weakly developed. Testes diagonal, entire or lobed. Ovary not lobed and situated between or anterior to the testes. The vitellaria occupy the lateral fields, meeting posteriorly like the intestinal cæca. The uterus has numerous transverse coils filling the central field. It contains numerous eggs which develop in the uterus, increasing in size, and the miracidium has characteristic eye-spots. Parasites of aquatic birds, usually in the body cavity, air-sacs or nasal cavity.

⑯

Genus **Typhlocœlum** Stossich, 1902

T. cymbium (Diesing, 1850) (syn. *Tracheophilus sisowi*) occurs in the trachea and bronchi of domestic and wild ducks. It measures 6-11·5 by about 3 mm. The body is widest at the middle and the ends are rounded. The intestinal ring has short median branches. The testes are not lobed and the ovary lies horizontal with the anterior testis in the posterior third of the body. The eggs measure 122 by 63 μ.

Life-Cycle.—Szidat has elucidated the remarkable life-cycle of this parasite. The miracidium which hatches from the egg and swims about in the water contains a single redia. When a suitable snail is reached the redia alone seems to enter it, while the miracidium dies off. *Helisoma trivolvis* and species of *Planorbis* are the chief intermediate hosts. The parasite thus skips the sporocyst stage and the redia, which settles down near the albuminous gland of the snail, begins to produce small numbers of cercariæ after about 11 days. The cercariæ have no tail and can be recognised by the complete intestinal ring; they are provided with a ventral sucker and an anterior boring apparatus. They do not leave the snail, but encyst in it after having escaped from the redia. The birds become infected by ingesting the infected snails. The larval worms probably reach the bronchi via the bloodstream, since they have been found in the lung tissue 4 days after infection. Szidat found the first eggs in the fæces 2 to 3 months after infection.

Pathogenicity.—The parasites cause obstruction of the trachea and the birds may die of asphyxia.

Treatment.—No satisfactory method of treatment is known.

Prophylaxis.—The birds should be kept away from suspected water and the extermination of snails may be considered.

Two other trematodes which belong to this family and may be harmful are *Typhlocœlum obovale* (Neumann, 1909), which occurs in the trachea, air-sacs and œsophagus of ducks and related wild birds, causing dyspnœa and asphyxia, and *Hyptiasmus tumidus* (Kossack, 1911), which is found in the nasal and orbital sinuses of ducks and geese, causing a catarrh.

Family PARAMPHISTOMIDÆ

These trematodes are usually thick and circular in transverse section. The ventral (posterior) sucker is situated at or close to the posterior extremity and may be very strongly developed. A large ventral pouch may be present. The anterior sucker sometimes has a pair of posterior pockets. A pharynx is absent, but the œsophagus is present and the intestinal cæca are simple. The cuticle is spineless. The genital pore opens ventrally, median, in the anterior third. The testes are frequently lobed and usually anterior to the small ovary. The vitelline glands are. as a rule, strongly developed. The uterus runs forwards in the dorsal part of the body and is coiled. Parasites of fishes, amphibia, reptiles, birds and mammals.

A large number of species have been described from domestic animals, As a rule they are not very pathogenic. The following species are the commonest and will give a general idea of the group.

Genus Paramphistomum Fischoeder, 1901

P. cervi (Schrank, 1790) (syn. *Amphistoma conicum*) occurs in the rumen and reticulum of the sheep, goat, cattle and many other ruminants, mainly in Africa, but also in other countries. The colour of live specimens is light red. It is one of the "conical flukes" which are pear-shaped, slightly concave ventrally and convex dorsally, with a large posterior subterminal sucker. The worm measures about 5-11 by 2-4 mm. The genital pore is situated at the end of the anterior third of the body. The testes are slightly lobed and tandem, anterior to the ovary. The eggs measure 114-176 by 73-100 μ.

Life-Cycle.—The life-history of the free-living stages is very similar to that of *Fasciola hepatica.* The intermediate hosts are snails of the genus *Bulinus*, as well as *Galba bulimoides techella, Planorbis planorbis*, and *Pseudosuccinea columella.* The cercaria is known as *Cercaria pigmentata* Sonsino, 1892, and can be recognised as an " amphistome " cercaria on account of the presence of anterior and posterior suckers. It has a moderately long, simple tail and a pair of eye-spots. The rest of the life-cycle and the pathogenicity are the same as in the following species.

Genus Cotylophoron Stiles and Goldberger, 1910

C. cotylophorum (Fischoeder, 1901) occurs in the rumen and reticulum of the sheep, goat, cattle and many other ruminants. It closely resembles *P. cervi*, but there is a genital sucker surrounding the genital pore. The eggs measure 125-135 by 61-68 μ.

Life-Cycle.—In South Africa *Bulinus schakoi* and *B. verreauxi* have been recorded as intermediate hosts by Cawston, who first described the cercaria as *C. frondosa*, and by Le Roux* who studied the life-cycle. The snails *Fossaria modicella* and *F. parva* are intermediate hosts in America, while *Indoplanorbis exustus* acts as such in India. The young stages in the snail comprise sporocysts, rediæ, daughter rediæ and cercariæ. The young cercaria has a pair of eye-spots which consist of pigment that later spreads over the whole body, so that the mature cercaria has a dark brown colour. On being swallowed by the final host the encysted cercaria is liberated in the intestine and settles down there for the first part of its life in the host. It attaches itself to the mucosa in any part of the small or large intestine and may also be found in the abomasum. After 3-8 weeks the flukes migrate forward to the rumen and reticulum, where they grow adult in about 2-4 months.

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* *16th Rep. Dir. Vet. Serv. and Anim. Ind., Union South Africa*, pp. 243-253. 1930.

Pathogenicity.—In heavy infections the immature parasites cause a marked irritation of the intestinal mucosa, resulting in diarrhœa. They also produce lesions of the mucosa and cause hæmorrhage into the intestinal lumen. The adult parasites in the fore-stomachs are practically non-pathogenic. In South Africa heavy infections occur in the summer rainfall area mainly in autumn and early winter, when the water in wet pastures—and with it the infected snails—become concentrated in pools and animals have access to such pools.

Symptoms.—Affected sheep and cattle become dull, weak and anæmic. There is a persistent, fœtid diarrhœa, the fæces often showing evidences of hæmorrhage in the small intestine. As a result of the anæmia œdemas develop, as in fascioliasis. The animals die mainly of exhaustion resulting from the diarrhœa.

Post-Mortem.—There is anæmia, sometimes œdemas and cachexia and fatty changes in the liver. The bloodvessels of the liver are markedly injected. The intestine contains a more or less hæmorrhagic fluid, the mucosa is thickened, especially in the duodenum, and on it are seen numerous small, reddish, oval bodies, 1-2 mm. long. These are the young parasites. The fore-stomachs may contain adult worms.

Diagnosis.—The immature parasites are usually found in fairly large numbers in the diarrhœic fæces. The disease must be differentiated from other diarrhœic conditions and in cattle especially from Johne's disease.

Treatment.—Tetrachlorethylene should be tried, or in the case of cattle hexachlorethane. The drugs should be administered in capsule or by stomach tube so as to ensure their entrance into the rumen, if the animal is being treated for the adult parasites. Treatment for the young flukes is not desirable while there is enteritis.

Prophylaxis.—As for fascioliasis.

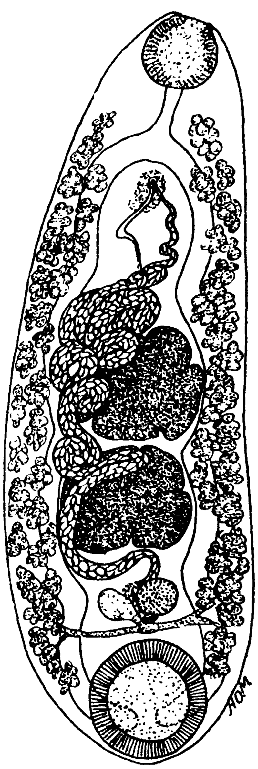

FIG. 36.—*Cotylophoron cotylophorum*. VENTRAL VIEW. (ORIGINAL.)

Genus **Gastrothylax** Poirier, 1883

G. crumenifer (Creplin, 1847) occurs in the rumen of sheep, cattle, zebu and buffalo in India, Ceylon and China. It is red when fresh, elongate, circular in transverse section and measures 9-18 by 5 mm. The worms of this genus are characterised by the presence of a large ventral pouch, opening anteriorly and extending over the whole ventral surface up to the posterior sucker. The genital pore opens into the pouch, half-way between the pharynx and the intestinal bifurcation. The intestinal cæca end at about the level of the anterior border of the testes, which are lobed and horizontal, with the ovary behind them. The uterus crosses from right to left at about the middle of the body. The eggs measure 115-135 by 60-70 μ.

Genus **Fischoederius** Stiles and Goldberger, 1910

F. elongatus (Poirier, 1883) occurs in the rumen of cattle and other *Bovidæ*. It is 10-20 mm. long, and the breadth is about one-quarter of the length. It closely resembles *Gastrothylax*, but one testis lies dorsal to the other and the uterus runs forward in the mid-line. The intestinal cæca are not widely separated and end a short distance behind the middle of the body. The eggs measure 144-152 by 73-75 μ.

F. cobboldi (Poirier, 1883) differs from the preceding species in being only 8-10 mm. long, while the intestinal cæca end at the posterior border of the posterior testis. This worm occurs in the rumen of cattle, zebu and gayal. The eggs measure about 115 by 74 μ.

Genus **Carmyerius** Stiles and Goldberger, 1910

C. spatiosus (Brandes, 1898) occurs in the rumen of cattle, zebu and antelopes and is 9-12 mm. long. It differs from *Fischoederius* in that the testes are horizontal. The posterior sucker is relatively small and spherical. The intestinal cæca reach the end of the second third of the body. The eggs measure about 118 by 76 μ.

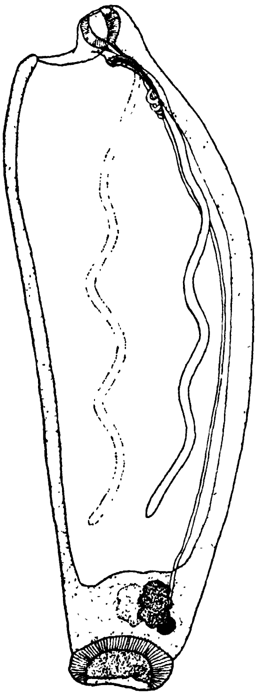

FIG. 37.—*Carmyerius spatiosus*, LATERAL VIEW. (ORIGINAL.)

C. gregarius (Looss, 1896) is found in the buffalo and cattle. It is 7-10 mm. long, and the intestinal cæca end a short distance behind the middle of the body.

The *life-cycles* of these paramphistomes are not known and the worms are usually not regarded as pathogenic, but *Fischoederius cobboldi* has been incriminated as the cause of death in cattle.

Where treatment should be necessary tetrachlorethylene or hexachlorethane is indicated.

Genus **Gastrodiscus** Leuckart, 1877

G. ægyptiacus (Cobbold, 1876) occurs in the large and small intestines of equines, pig and warthog in Africa and India. It is pink in colour when fresh, and measures 9-17 by 8-11 mm. There is an anterior, more or less cylindrical, part which is up to 4 mm. long and 2·5 mm. wide, while the rest of the body is saucer-shaped, with the margins curved inwards. The ventral surface is covered by a large number of regularly arranged papillæ. The posterior sucker is small and subterminal. The oral sucker has two postero-lateral pouches. The intestine branches at the anterior border of the wide portion and the cæca continue to near the hind end of the body. The testes are lobed, slightly diagonal and lie behind the middle with the ovary posterior to them. The vitellaria occupy the lateral fields. The genital pore opens at the level of the intestinal bifurcation. The eggs are oval and measure 131-139 by 78-90μ.

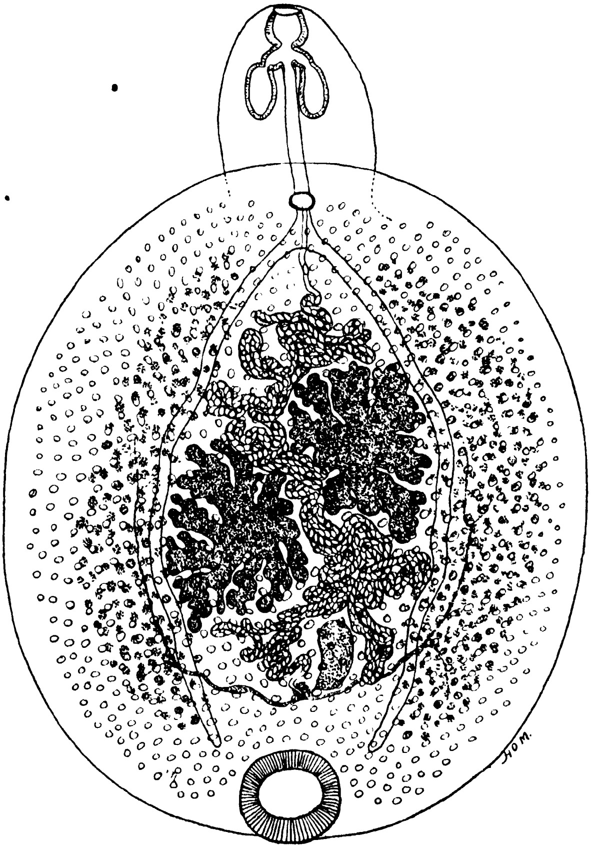

FIG. 38.—*Gastrodiscus ægyptiacus*, VENTRAL VIEW. (ORIGINAL.)

Life-Cycle.—In Egypt snails of the genus *Cleopatra* are considered to be the intermediate hosts and the cercariæ encyst in water.

Pathogenicity.—Little is known with regard to the pathogenicity of this parasite, and it is generally not considered to be important.

Treatment.—When necessary, carbon tetrachloride or tetrachlorethylene would be the drugs indicated.

Family STRIGEIDÆ

These worms are characterised by a constriction which divides the body into an anterior, flattened or cup-shaped and a posterior, cylindrical part. The latter contains the gonads. The ventral sucker may be poorly developed or absent, and behind it there is usually a special adhesive organ. The genital pore opens posteriorly in a depression or "bursa copulatrix." The testes lie tandem, with the ovary anterior to them. Cirrus-sac and pouch are usually absent. The uterus contains relatively few large eggs. Parasites in the alimentary canal, chiefly of birds. The cercariæ are furcocercous, provided with a pharynx, and develop in snails from sporocysts. They enter a second intermediate host, which may be a fish, snail, leech, etc.

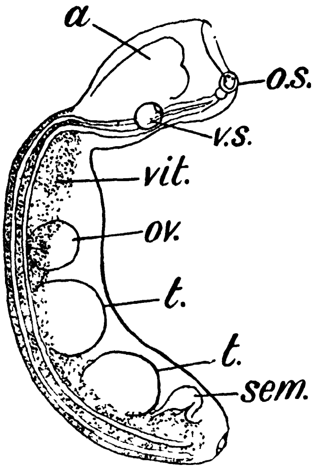

FIG. 39. — *Apatemon gracilis*, LATERAL VIEW. (FROM BAYLIS, AFTER BRANDES.)

a., Adhesive organ; *o.s.*, oral sucker; *ov.*, ovary; *sem.*, seminal vesicle; *t.*, *t.*, testes; *vit.*, vitellaria; *v.s.*, ventral sucker.

Genus Apatemon Szidat, 1929

A. gracilis (Rudolphi, 1819) occurs in the intestine of the pigeon, duck and wild duck in Europe. It is not over 2·3 mm. long and is concave dorsally. The anterior cup-shaped part forms about one-third of the total length. It contains an adhesive organ. The cirrus and cirrus-sac are absent. The "bursa" contains at its base a weak copulatory organ or genital cone. The vitellaria are restricted to the posterior part of the body. The eggs measure 100-110 by 75 μ.

Life-Cycle.—The eggs develop after having been passed in the fæces of the host and the miracidium hatches under favourable conditions in about 3 weeks. After entering a suitable snail the sporocyst develops. It is very slender and about 20 mm. long. The cercariæ are formed directly by the sporocysts. According to Szidat* the secondary intermediate hosts are the leeches *Hæmopis sanguisuga* and *Herpobdella atomaria.*

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* *Ztschr. f. Parasitenk.*, 1 (4/5): 612-764. 1931.

Genus **Parastrigea** Szidat, 1928

P. robusta Szidat, 1929, occurs in the intestine of the domestic duck in Europe. It is not over 5 mm. long and resembles the previous species, but the anterior portion has two large, lateral expansions and a narrow opening, while the vitelline glands are mainly situated in the lateral expansions and the adhesive organ, but also partly in the posterior part of the body. The eggs measure 90-100 by 50 μ.

Life-cycle unknown.

A number of other species are also known, especially from ducks.

Pathogenesis and Symptoms.—The parasites attach themselves to the mucosa of the intestine by means of the anterior cup-shaped part of the body, into which they draw a number of villi, constricting them strongly at their bases. The bloodvessels in the villi become markedly hyperæmic and burst, discharging the blood into the cavity, from which it is ingested by the worm. The constricted villi then degenerate and, according to Szidat, are apparently digested by the secretion of a gland in the adhesive organ. The pre-digested material is subsequently ingested by the parasite. It is obvious that this method of feeding will cause anæmia and severe irritation in heavy infections, resulting in a hæmorrhagic enteritis and loss of condition, or the death of the bird.

Diagnosis is made by finding the eggs in the fæces or the worms at autopsy.

Treatment.—Carbon tetrachloride is indicated in doses of 1-2 c.c.

Prophylaxis should be directed against the intermediate hosts. As there are apparently two of these, the chances of success in prevention are increased by this factor.

Genus **Cotylurus** Szidat, 1929

C. cornutus (Rud, 1809) occurs in the small intestine of the pigeon and the duck in Europe. It is only 1·2-1·5 mm. long and 0·5 mm. thick. In its morphology it resembles *Apatemon gracilis*, but the bursa contains a strong copulatory organ. The eggs measure 90-110 by 56-60 μ.

Life-Cycle.—The miracidia hatch in 6-8 days and penetrate into snails, *Limnæa stagnalis* and *Stagnicola palustris*, in which cercariæ develop out of the sporocysts. The cercariæ are furcocercous and have a pharynx. They emerge from the first intermediate host and penetrate into other snails of the same species or other species of the genera *Limnæa* or *Planorbis*. Pigeons become infected by ingesting infected snails. Even nestling pigeons are infected through their parents' feeding them out of their crops.

Pathogenicity.—Baudet describes serious losses of pigeons caused by this parasite. The worms were deeply embedded in the mucosa of the small intestine and caused a hæmorrhagic enteritis. The pigeons showed great dullness and diarrhœa.

Family SCHISTOSOMATIDÆ

These are elongate, unisexual and dimorphic trematodes, which inhabit the bloodvessels of their hosts. The female is slender and usually longer than the male, and is carried by the latter in a ventral, gutter-like groove, the " canalis gynæcophorus," formed by the incurved lateral edges of the body. The suckers are weak and close together or absent. There is no pharynx and the œsophagus is long. The intestinal branches usually unite posteriorly to form a single tube which extends to the hind end. The genital pore lies behind the ventral sucker. The testes form four or more lobes, situated anteriorly or posteriorly. The ovary is an elongate, compact organ, lying in front of the posterior union of the intestinal branches. The vitelline gland occupies the part of the body behind the ovary. The eggs are thin-shelled and have no operculum. They are laid by the females in the small bloodvessels of the intestinal wall or the urinary bladder and pass through the tissues, leaving the host with the fæces or urine. The cercariæ are furcocercous, without a pharynx, and develop from sporocysts without a redia stage.

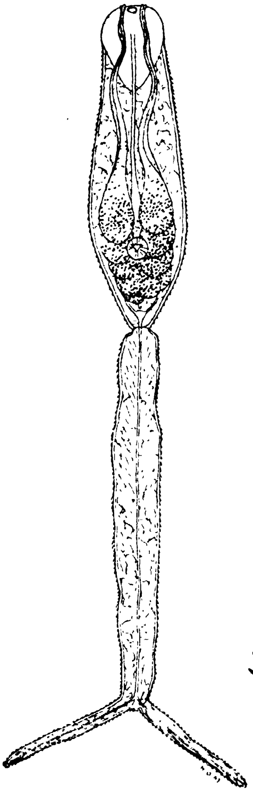

FIG. 40.—CERCARIA OF *Schistosoma bovis*. (AFTER MÖNNIG.)

Genus **Schistosoma** Weinland, 1858

90 **S. japonicum** Katsurada, 1904, occurs in the portal and mesenteric vessels of man as well as cattle, horse, sheep, goat, dog, cat, rabbit and pig in the Far East. The male is 9·5-20 mm. long and 0·55-0·967 mm. wide. The suckers lie close together near the anterior end. The cuticle is spiny on the suckers and in the gynæcophoral canal. The testes consist of 6-8 lobes in a longitudinal row, lying behind the genital pore, which opens directly posterior to the ventral sucker. In both sexes the œsophagus is surrounded by a group of glands and the intestine bifurcates before reaching the level of the ventral sucker, again uniting in the last quarter of the body. The female is 15-26 mm. long and about 0·3 mm. thick. The ovary lies behind the middle and the vitelline gland fills the posterior quarter.

The oötype is situated directly anterior to the middle, opening into the long uterus, which extends forwards to the genital pore. The eggs are passed in the fæces of the host and measure 70-100 by 50-80 μ. They are short, oval, and may have a small lateral spine or knob.

Life-Cycle.—The ovigerous female penetrates deeply into the small vessels of the mucosa or sub-mucosa of the intestine, laying the eggs in the capillaries. Some eggs may be carried away by the bloodstream and are then found in the liver and other organs. They are, however, normally passed into the intestinal lumen and out in the fæces. When laid the eggs are immature and continue their development as they pass out. The intermediate hosts are the small amphibious snails *Oncomelania* (*Hemibia*) *hupensis*, *O.* (*Hypsobia*) *nosophora*, *O.* (*H.*) *formosana* and *O. quadrasi*, which have elongate spiral shells and are operculate. There are two generations of sporocysts, the second forming the cercariæ. The latter swarm out of the snail and swim about in the water. Infection takes place when the final host comes in contact with infected water; the cercariæ penetrate through the skin, being assisted by the secretion of the cephalic salivary glands which digest the tissues. In this way they reach the blood and are transported via the lungs to the systemic circulation. Those that reach the abdominal vessels and pass to the portal veins develop further and become mature in about 4 weeks. The others will reach other organs in which they may produce lesions, but they eventually die and do not reach the adult stage.

Pathogenesis and Symptoms.—The penetration of the cercariæ through the skin causes a dermatitis which will, however, not be observed in animals unless they are subjected to frequent and severe infections. The passage through the lungs may cause pneumonia in gross infections. Those cercariæ that reach organs like the kidneys may cause small hæmorrhages by breaking out of the bloodvessels. The abdominal organs, like the liver, may become congested during the early stages of the disease. The most serious damage is caused by the adult parasites in the egg-laying stage, on account of the irritation caused by the eggs in the intestinal wall and in other organs which they may reach accidentally. The masses of eggs become surrounded by inflamed areas and an infiltration of leucocytes, especially eosinophiles, giving rise to a rather characteristic type of abscess. The abscesses in the intestinal wall usually burst, discharging their contents into the lumen of the gut, and this is followed by healing through the formation of scar tissue. The main symptom resulting from these pathological changes is diarrhœa with the eggs of the parasites in the fæces, frequently accompanied by mucus and blood.

In the liver the abscesses become encapsulated and will finally calcify, a large number of such foci leading to enlargement of the organ, marked cirrhosis and ascites. The spleen and mesenteric lymph glands are usually also affected, becoming congested and showing an increase of fibrous tissue. It is believed that toxins secreted by the parasites are responsible for these lesions. The consequent symptoms are abdominal pain, fever and loss of appetite and condition.

The parasites feed on blood and cause anæmia with its sequelæ, while the hæmatin pigment, which is regurgitated by the parasites after they have digested the erythrocytes, causes a discoloration of various organs. Eggs may also reach the brain and produce nervous symptoms. The weakened system is easily overcome by secondary infections.

Post-Mortem.—Anæmia and emaciation are marked. Ascites is usually present. The intestinal wall is much thickened, showing the presence of scar tissue and frequently papillomatous growths of the mucosa. Cirrhosis of the liver is a conspicuous lesion and the walls of the portal veins are thickened. The mesentery, the mesenteric lymph glands and the spleen are frequently altered on account of the presence of an abnormal amount of connective tissue. Pigment is seen especially in the liver and spleen. A search should be made for the parasites while the intestine is still attached to the mesentery, as they are not easily found after exenteration of the organ.

Diagnosis.—The symptoms alone will not suffice to arrive at a definite diagnosis, but they should indicate the necessity of fæces examination, which will reveal the eggs of the parasites.

Treatment.—Sodium antimony tartrate gives the best results and is administered intravenously in small, repeated doses. For human cases the dose is 0·07-0·1 gm. (1-1½ grains) in 1 per cent. solution on alternate days or at longer intervals, depending on the reaction and the condition of the patient. The treatment is continued until a total of 1·7-2 gm. have been administered. It should be remembered that treatment for schistosomiasis has to be carried out gradually, as more harm than good will result if a large number of parasites are killed off all at once and carried to the liver, where they could cause embolism of the portal vessels.

Prophylaxis.—Apart from the obvious measure of snail extermination, which presents many difficulties, the problem is mainly connected with man as the most important host of the parasite, and is a matter of proper treatment of night-soil which is used as fertiliser. Faust recommends that the night-soil should be allowed to ferment, in order to kill the eggs, before it is spread on the fields. In Japan the infection of domestic and wild mammals is more important than in China and should receive the attention of the veterinarian.

S. bovis (Sonsino, 1876) (syn. *S. matthei*, Veglia and Le Roux, 1929) occurs in the portal and mesenteric vessels of cattle, sheep, goats, the sitatunga (*Limnotragus spekei*) and more rarely equines in Southern Europe, Southern Asia and Africa. Blackie* records this parasite also from the baboon (*Papio porcarius*) in Southern Rhodesia, and he was able to infect the grey monkey (*Cercopithecus pygerythrus*). Blackie, as well as other authors, record this parasite from man, but the cases are rather infrequent. MacHattie, Mills and Chadwick,† in reviewing these cases and after attempted infection of one of them with *S. bovis*, conclude that this parasite does not occur in man and that the reported cases were infected with *S. hæmatobium*, a human parasite which is indistinguishable from *S. bovis*. The eggs of *S. hæmatobium* are usually passed in the urine, rarely in the fæces, and as a rule they are oval, but spindle-shaped eggs resembling the typical *S. bovis* egg, which is passed in the fæces, may occur.

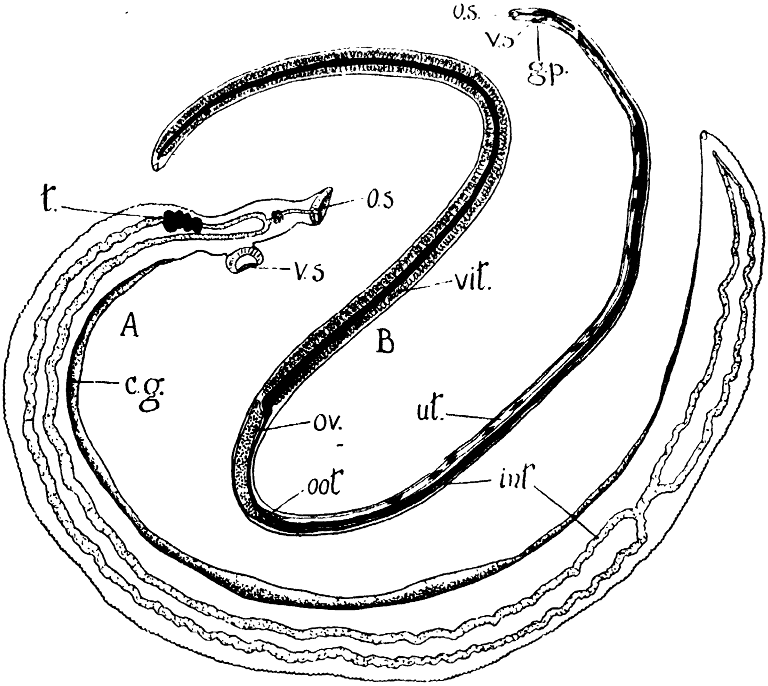

FIG. 41.—*Schistosoma bovis*. (ORIGINAL.)

A, Male; B, female; *c.g.*, canalis gynæcophorus; *g.p.*, genital pore; *int.*, intesti; *o.s.*, oral suckerne; *oot.*, oötype; *ov.*, ovary; *t.*, testes; *ut.*, uterus; *v.s.*, ventral sucker; *vit.*, vitellaria.

The males are 15-22 mm. long and 1-2 mm. wide, depending on the degree of folding of the lateral edges. The female is 12-28 mm. long,

* Memoir Series, London School Hyg. and Trop. Med., No. 5. 1933.

† *Trans. Roy. Soc. Trop. Med. Hyg.*, 27 (2): 173-184. 1933.

The suckers and the body of the male behind the suckers are armed with minute spines, while the dorsal surface of the male bears small cuticular tubercles. The intestine bifurcates at the level of the ventral sucker and reunites in the female just behind the middle of the body, or sometimes farther back, being continued as a single cæcum. In the male the cæca may reunite far back or not at all, or there may be several junctions between them and two posterior cæca. The male has 3-6 testes in a longitudinal row, situated a short distance behind the ventral sucker. The ovary is about 1 mm. long and lies at the middle of the body behind Mehlis' gland. The uterus runs forwards from this point and may contain a large number of eggs. The vitelline gland occupies as a rule the posterior half of the body behind the ovary, but in some females it may fill only the posterior quarter. The eggs are usually spindle-shaped, but small ones are frequently oval, and when passed in the fæces measure on the average 187 by 60 μ; the limits given by various authors are 130-280 by 40-95 μ.

Life-Cycle.—The known intermediate hosts are *Bulinus contortus*, *B. truncatus*, *Physopsis africana* and *P. globosa*, in which the cercariæ develop from daughter sporocysts which replace the redia stage. The cercaria is of the furcocercous type without a pharynx, and is armed with spines. It has four pairs of cephalic glands, two acidophil and two basophil. Infection of the host may take place through the skin, but in the case of sheep the cercariæ are probably swallowed with water.

Pathogenesis and Symptoms.—On the whole, there is much resemblance to schistosomiasis japonica. The young parasites cause some damage during migration, but most of the lesions are due to irritation produced by the eggs of the parasites in the intestine and other organs and the blood-sucking habits of the worms. According to Le Roux,* the eggs in the intestinal wall are surrounded by leucocytes, but neither erosions nor necrosis of the mucosa are seen nor has he found any papillomatous growths of the mucosa, as described by other authors. The affected animals become anæmic, lose condition and show alternate diarrhœa and constipation, gradually wasting away until death takes place. The fæces contain blood and mucus and the eggs can be found in them in large numbers.

Post-Mortem.—Anæmia and emaciation are present and there may be ascites and hydropericard. A characteristic feature is the marked grey pigmentation of the lungs and liver. The parasites in the mesenteric veins should be searched for before the intestine is exenterated. The liver may be larger or smaller than normal, depending on the stage of the disease, and is markedly cirrhotic in older cases, the surface being conspicuously uneven. On microscopical examination there is pigment in the liver and numerous eggs may be found, surrounded by cellular infiltration and fibrous tissue. The intestine shows the presence of eggs in its wall in the form of grey clusters or thickenings which are opaque and grating to the knife. The mucosa usually shows small hæmorrhages and the submucosa may be thickened. The spleen may be slightly swollen and pigmented and the pancreas and lymph glands are usually pigmented.

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* 15*th Rep. Dir. Vet. Serv.*, *Union South Africa*, pp. 335-438. 1929.

Diagnosis.—Finding the eggs in the fæces will confirm the diagnosis made tentatively on the symptoms.

Treatment.—Good results are recorded from the intravenous injection of tartar emetic as a 6 per cent. sterile solution, giving a total of ten injections, beginning with 2 c.c., then 3 c.c., and thereafter 4 c.c., on alternate days, for sheep. For cattle 6 per cent. antimosan has been used, giving ten injections of 25 c.c. each on alternate days.

Prevention can be successfully accomplished on the lines described in the case of *Fasciola hepatica.*

Other schistosomes which occur in domestic animals are the following:

1. **S. spindalis** Montgomery, 1906, occurs in the mesenteric veins of cattle, goats, sheep, dog, and zebu (*Bos bubalis*) in India and Sumatra, and in the reedbuck (*Redunca arundinum*) and the lechwe (*Onotragus lechwe*) in Rhodesia. The male is 5·6-13·5 mm. long and the female 7·18-16·2 mm. There are 3-7 testes. The eggs measure 160-400 by 70-90 μ and are elongate, flattened on one side and have a terminal spine. They are usually passed in the fæces, but sometimes also in the urine. The intermediate hosts are snails of the genus *Planorbis*, *Indoplanorbis exustus*, and rarely *Limnæa acuminata.*

2. **S. nasalis** Rao, 1932, closely resembles *S. spindalis.* It causes " snoring disease " of cattle, goats and horses in India* and similar cases have been reported from Louisiana, U.S.A.† The male is 6·3-11 mm. long, coarsely tuberculate, and has 2-4 testes. The female is 5-11 mm. long. The eggs are boomerang-shaped, 336-581 by 50-80 μ. Intermediate hosts are *Limnæa luteola*, *L. acuminata* and *Indoplanorbis exustus.* The parasites develop in the veins of the nasal mucosa, causing a marked rhinitis with a muco-purulent discharge. The mucosa is studded with small abscesses which contain the eggs of the worms, and later shows much fibrous tissue and proliferating epithelium. Symptoms of coryza with sneezing are succeeded by dyspnœa and snoring. Good results have been obtained from injections of antimosan and tartar emetic.

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* *Ind. Journ. Vet. Sc. and Animal Husb.*, 4 (1): 1-38. 1934.

† *Vet. Med.*, 28 (7): 279. 1933.

3. **S. indicum** Montgomery, 1906, occurs in the portal, pancreatic, pelvic, hepatic and mesenteric veins of sheep, goats, cattle, equines and camels in India. The male is 5-19 mm. long and the female 6-22 mm. There are 5-12 testes. The eggs are oval with a terminal spine and measure 57-140 by 18-72 μ. They are passed in the fæces of the host. The eggs cause nodules in various organs and cirrhosis of the liver with debility, especially in horses.

4. **S. suis** Rao and Ayyar, 1933, occurs in the pig and the dog in India. It may be identical with *S. incognitum* of Chandler, 1926, according to Bhalerao. The egg is yellowish-brown, suboval with one side flattened, with a small, stout spine inclining towards the flattened side. In the uterus it measures about 90 by 41 μ.

5. **Ornithobilharzia bomfordi** (Montgomery, 1906) occurs in the mesenteric veins of the zebu (*Bos bubalis*) in India. The male is 6-9 mm. long and the female 3-7·3 mm. The male has about 60 testes and the female has a long posterior cæcum. The eggs are oval with a posterior spine and measure 100-136 by 44-60 μ. They are found in the fæces of the host.

6. **O. turkestanicum** (Skrjabin, 1913)* occurs in the mesenteric veins of sheep, goat, camel, horse, donkey, mule, water buffalo, cattle and the cat in Russian Turkestan, Kazakstan, Mongolia, Iraq and France. It is a small species, the male being 4·2-8 mm. long and the female 3·4-8 mm. There are 70-80 testes and the ovary is spirally coiled. The intestinal cæcum of the female is about three times as long as the divided portion. The uterus contains one egg at a time. The eggs measure 72-77 by 18-26 μ. They have a terminal spine and a short appendage at the other end. It is of little significance in large animals, but leads to permanent debility in sheep and goats, causing marked liver cirrhosis and nodules in the intestines. The intermediate host is the snail *Limnæa tenera euphratica*, according to MacHattie.

Genus **Bilharziella** Looss, 1899

B. polonica (Kowalewski, 1896) occurs in the mesenteric and pelvic veins of wild and domestic ducks in Europe and North America. The body is flattened in both sexes and usually lancet-shaped in the posterior half. The male is about 4 mm. long and 0·52 mm. wide, and the female is 2·1 mm. long and 0·25 mm. wide. The intestinal branches reunite near the middle of the body, forming a cæcum which runs a zigzag course to the posterior extremity. The male genital pore opens to the left of the mid-line, near the middle of the body. The testes are numerous;

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* *Trans. Roy. Soc. Trop. Med. Hyg.*, 30 (1): 115-124. 1936.

one lies anterior to the reunion of the intestinal branches and the rest are arranged in a row on either side of the cæcum. The female genital pore is situated behind the ventral sucker. The uterus contains one egg at a time. The eggs are narrow and elongate anteriorly and swollen posteriorly, with a terminal spine; they measure 0·4 by 0·1 mm.

Life-Cycle.—The eggs are laid in the small vessels of the intestinal wall with the narrow part directed towards the lumen of the gut. They gradually penetrate through the wall and are passed out in the fæces. Such eggs are still in the early stages of development. The intermediate host is the snail *Planorbis* (*Coretus*) *corneus*, according to Szidat.* The cercariæ are of the usual type and have a pair of pigmented eye-spots. There are three pairs of basophil and three pairs of acidophil cephalic glands. Infection takes place through the skin.

Pathogenicity.—The eggs have been found only in the wall of the intestine, where they may occasionally produce inflammatory processes with infiltration of leucocytes and connective tissue proliferation. The parasite is apparently not very pathogenic.

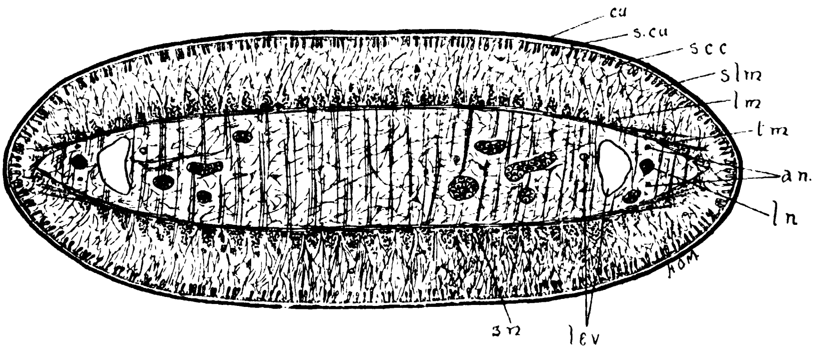

FIG. 42.—TRANSVERSE SECTION OF A CESTODE: DIAGRAMMATIC. (ORIGINAL.)

a.n., Accessory nerves; *cu.*, cuticula; *l.e.v.*, longitudinal excretory vessels; *l.m.*, longitudinal muscles; *l.n.*, lateral nerve; *s.c.c.*, subcuticular cells; *s.cu.*, subcuticula; *s.l.m.*, subcuticular longitudinal muscles; *s.n.*, submedian nerve; *t.m.*, transverse muscles.

Treatment and Prevention.—Nothing is known with regard to treatment except that Fuadin is ineffective. It would be desirable to exterminate the snail host where the parasite occurs.

CLASS CESTODA

The cestoda are endoparasitic worms with an elongate, flat body and without a body-cavity. The head or *scolex* is usually provided with suckers and hooks and is connected to the body by a neck in most cases. The body or *strobila* consists of a number of segments or *proglottides*.

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* *Arch. f. Geflügelk.*, 3 (3): 78-87. 1929.

There is no alimentary canal. Each proglottis usually contains one or two sets of male and female reproductive organs. The development, where known, includes the passage through an intermediate host.

Morphology.—The cestodes vary in size from a few millimetres to several metres in length. The scolex is usually more or less globular and bears two or four suckers with muscular walls which may be armed with hooks. Anteriorly the scolex may be armed with a protrusible part, the *rostellum*, which may bear one or more rows of hooks. These hooks vary much in shape, but generally handle, guard and blade portions can be recognised. The hooks are sometimes lost, especially when they are small.

The strobila may consist of a few or numerous proglottides, and these may vary considerably in shape and size in different species. They are formed behind the head, so that the anterior ones are the youngest, and they increase in size and the development of their internal parts progresses as they are pushed farther and farther away from the scolex by the younger segments.

The structure of the body is very similar to that of the trematodes. It is covered externally by a cuticula with fine pores, through which the parasite absorbs its nourishment. Beneath this covering is a subcuticula and weak layers of transverse and longitudinal muscles. The body is filled with a parenchyma, as in the trematodes, and in this tissue lie, more centrally, strong bundles of longitudinal muscle fibres. Inside this zone there is a layer of transverse muscles which divide the body into cortical and medullary portions. Dorso-ventral muscles are also present, but are weakly developed. The cortical parenchyma contains a large number of small, oval, calcareous corpuscles, which are sometimes very useful for the identification of cestode tissue. The medulla contains the excretory, nervous and reproductive organs.

The excretory system consists of flame-cells and efferent canals as in the trematodes. There are usually on either side two longitudinal canals, a larger ventral and a smaller dorsal, each pair being connected by a transverse vessel in the posterior part of the proglottis, and all are joined together by transverse loops in the scolex. Frequently a small bladder occurs in the terminal segment, but it is lost with the latter and then the canals open separately.

The central part of the nervous system is situated in the scolex and consists of several ganglia and commissures, from which two large and several smaller nerve trunks run through the strobila. The main trunks are lateral to the large excretory canals.

The male genital organs are the first to develop in the young proglottides. More posteriorly the female organs originate, and when they are mature fertilisation takes place and eggs are formed. These usually remain and develop in the proglottis, and when it is " ripe " it contains only vestiges of the genital organs and the eggs and it drops off from the body. The male organs consist of one or a few, or more usually a large number of testes, discharging into vasa efferentia, which join to form a vas deferens. This may form a seminal vesicle and ends in a cirrus which is surrounded by a cirrus-sac. The male and female genital pores frequently lie close together in a shallow sinus on the lateral margin of the proglottis (most *Cyclophyllidea*), or on the ventral surface (many *Diphyllobothriidæ*), and self-fertilisation of individual segments occurs.

The female pore leads into a vagina, a narrow duct which frequently bears a seminal receptacle and ends in the oötype, surrounded by Mehlis' gland, where it is joined by the oviduct and the vitelline duct. The ovary is single and usually lobed. The vitelline gland is usually compact in the *Cyclophyllidea*, but in some cases it is divided into follicles, especially in the *Diphyllobothriidæ*. From the oötype the uterus arises. It may open distally and discharge the eggs, but more usually it ends blindly and assumes various shapes as it becomes filled. In some cases the uterus disappears after discharging its eggs into a special thick-walled par-uterine organ (*e.g. Avitellina*) or into a number of parenchymatous egg-capsules.

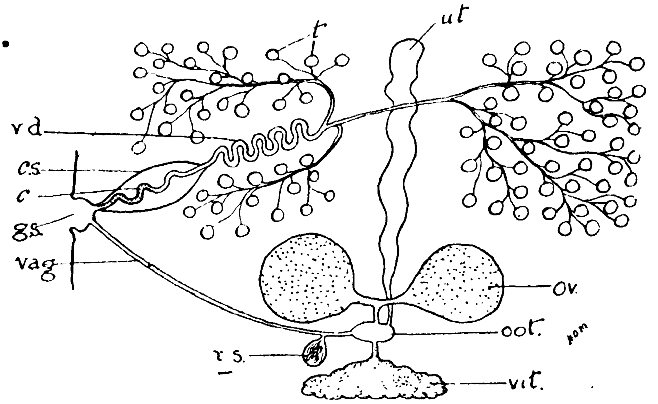

FIG. 43.—REPRODUCTIVE ORGANS OF A CESTODE: DIAGRAMMATIC. (ORIGINAL.)

c., Cirrus; *c.s.*, cirrus-sac; *g.s.*, genital sinus; *oot.*, oötype; *ov.*, ovary; *r.s.*, receptaculum seminis; *t.*, testes; *ut.*, uterus; *vag.*, vagina; *v.d.*, vas deferens; *vit.*, vitellarium.

In most cases the embryonic development takes place in the uterus and the eggs, when laid, contain a spherical or ovoid embryo provided with three, rarely five, pairs of hooks and known as the "hexacanth embryo." During its development a number of embryonic cells usually separate from the true embryo and form a special embryonic egg-shell within the original shell. The latter is sometimes lost and there remains the embryonic shell with the embryo, known as the " oncosphere," or, in the *Diphyllobothriidæ*, the " coracidium."

Development.—The *Diphyllobothriidæ* rather resemble the trematodes in their development and will be treated later. In the *Cyclophyllidea* the egg hatches after having been swallowed by the intermediate host, and the hexacanth embryo penetrates into the intestinal wall in order to reach a suitable part of the body for its further development. Here it grows into a cyst composed of an outer cuticle and an inner germinal layer, containing a cavity filled with fluid. It develops one or more heads on its wall or in special brood-capsules. The wall forms an invagination, at the bottom of which the rostellum with the hooks and the suckers develop in such a way that the head is at first turned inside out, but it soon rises up in the lumen of the invaginated part, where it usually remains. It is thus surrounded by two walls, with the cavity of the cyst between them. This bladderworm, as it is called, is ready for further development in the final host as soon as the hooks and suckers are sufficiently developed to enable the parasite to attach itself in the intestine.

The common forms of cyclophyllidean bladderworms can be classified as follows:

Cysticercus : a bladderworm with a large vesicle and one head; usually found in vertebrates.

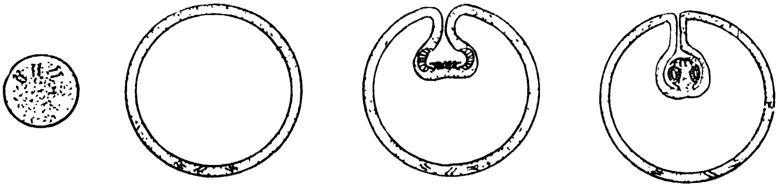

FIG. 44.—STAGES IN THE DEVELOPMENT OF A CYSTICERCUS. (ORIGINAL.)

Cysticercoid : a small vesicle, practically without a cavity, and one head; usually found in invertebrates.

Cercocystis : a cysticercoid with a tail-like appendage to the vesicle.

Multiceps : a large cyst usually, with a number of heads developing on the wall.

Echinococcus : a large cyst forming brood-capsules in which the heads normally develop.

Dithyridium : an elongate larva with a solid body into which the head is invaginated.

The bladderworm is passively transferred to the final host when the latter ingests the infected intermediate host. In the case of *Hymenolepis nana*, a parasite of the rat, the latter itself acts as the intermediate host, since the cysticercoid develops in the mucosa of the intestine and proceeds with its development to the adult stage in the same host. After its arrival in the intestine the bladderworm evaginates its head and attaches it to the mucosa. The bladder is discarded and the proglottides develop.

The resistance of tapeworm eggs is in general probably rather weak, and they usually die when they become desiccated or when the proglottis in which they are contained decomposes.

The bladderworms may live for a fairly long period, but later die and become calcified. Their metabolism must be very low, especially after development has been completed, and this, together with the fact that they are situated outside of the alimentary canal and are usually enclosed in a fibrous cyst which is normally avascular, probably accounts for the failure of all drugs that have so far been tried for the treatment of animals infected with bladderworms.

Family DIPHYLLOBOTHRIIDÆ

The *Diphyllobothriidæ* belong to the order *Pseudophyllidea*, which usually bear on the scolex two elongate grooves, called "bothridia," instead of suckers. They differ markedly in their morphology and development from the *Cyclophyllidea*. The only genus of interest for the purposes of this book is the following:

Genus **Diphyllobothrium** Cobbold, 1858

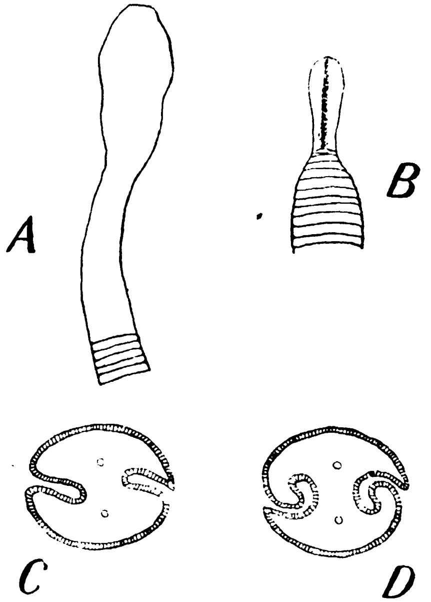

FIG. 45.—*Diphyllobothrium latum*, SCOLEX. (FROM BAYLIS, AFTER STEIN.)
A, Lateral view; *B*, dorsal view; *C*, *D*, transverse sections at different levels.

D. latum (Linnæus, 1758) occurs in the small intestine of man, dog, pig, cat, fox, polar bear and other fish-eating animals in many parts of the world. It grows up to 9 m. or even longer and 2 cm. wide, and consists of 3,000-4,000 segments. When fresh the colour is yellowish-grey, with dark, central markings caused by the uterus and eggs. The scolex is almond-shaped, 2-3 mm. long, provided with dorsal and ventral, elongate bothridia. The neck varies in length with the state of contraction. The proglottides are broader than long anteriorly and about square posteriorly. There are a large number of testes lying dorsally in the lateral parts of the proglottides, and the vas deferens winds forwards to the cirrus, opening in the mid-line on the ventral surface. The vagina opens immediately behind the cirrus and runs straight back to join the oviduct. The ovary is bilobed, lying in the posterior region. The vitellaria are follicular and are situated in the lateral regions of the cortex. The uterus winds forwards from the oötype to the uterine pore, opening behind the genital pore. The eggs are light brown, operculate and measure 67-71 by 44-54 μ. They are found in the fæces of the host.

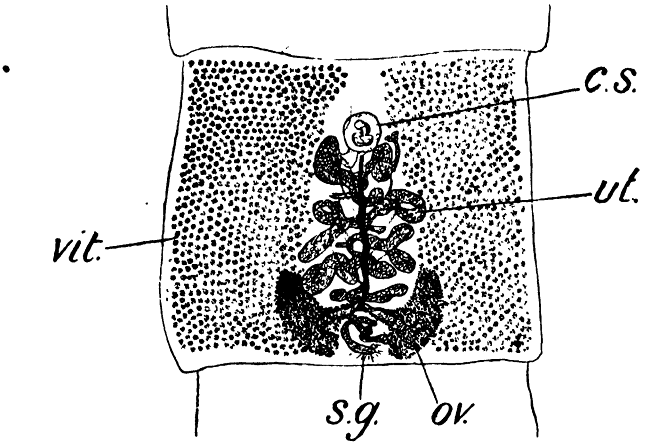

FIG. 46.—*Diphyllobothrium latum*, MATURE SEGMENT. (FROM BAYLIS, AFTER STEPHENS.) *c.s.*, Cirrus-sac; *ov.*, ovary; *s.g.*, shell-gland; *ut.*, uterus; *vit.*, vitellaria.

Life-Cycle.—The eggs develop for several weeks after leaving the body of the host, before the embryo is ready to hatch in water. The coracidium has a ciliated covering, corresponding to the embryonic egg-shell of the *Cyclophyllidea*. It swims about in the water and dies fairly soon unless it is ingested by a suitable crustacean. *Cyclops strenuus*, *Diaptomus gracilis* and other species of these two genera are known to act as the first intermediate hosts. In their body-cavity a larval stage, known as a procercoid, develops in 2-3 weeks. If the copepod is then swallowed by a suitable fish, the larval worm penetrates through the intestine to the muscles or other organs, where it develops into a plerocercoid. This is an elongate, solid larval stage with a head resembling that of the adult. It is 1-2 cm. long. A large number of fishes are known to act as secondary intermediate hosts, including pike, trout, salmon and perch. The final host becomes infected through eating raw or insufficiently cooked fish or raw caviare. The worm grows adult in dogs in about 4 weeks.

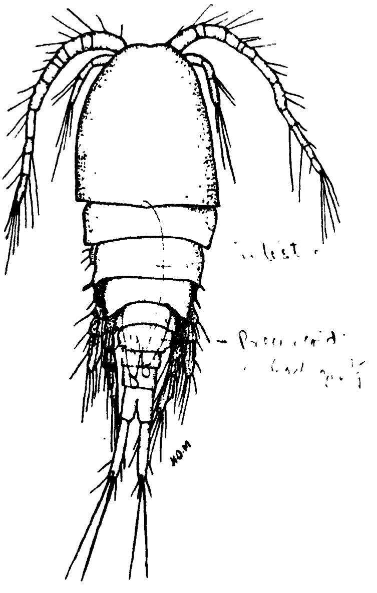

FIG. 47.—*Cyclops strenuus*, DORSAL VIEW. (ORIGINAL.)

Pathogenicity.—The pathogenicity of this parasite for dogs and cats is not well known and it is chiefly important as a parasite of man, who is apparently its normal host. It has been shown that only a small percentage of the eggs passed by dogs will hatch, while a much larger percentage of those of human origin develop and the worms reared in dogs are generally smaller than those from human cases.

In man the worm produces severe anæmia, perhaps as the result of absorption of waste products of the parasite or of toxins liberated by it.

Treatment and Prophylaxis. — Dogs can probably be successfully treated with arecoline hydrobromide as for other tapeworms, and cats with kamala. The infection can be avoided by preventing the animals from eating raw or insufficiently cooked fish, and this is an important measure in the control of the parasite as far as man is concerned.

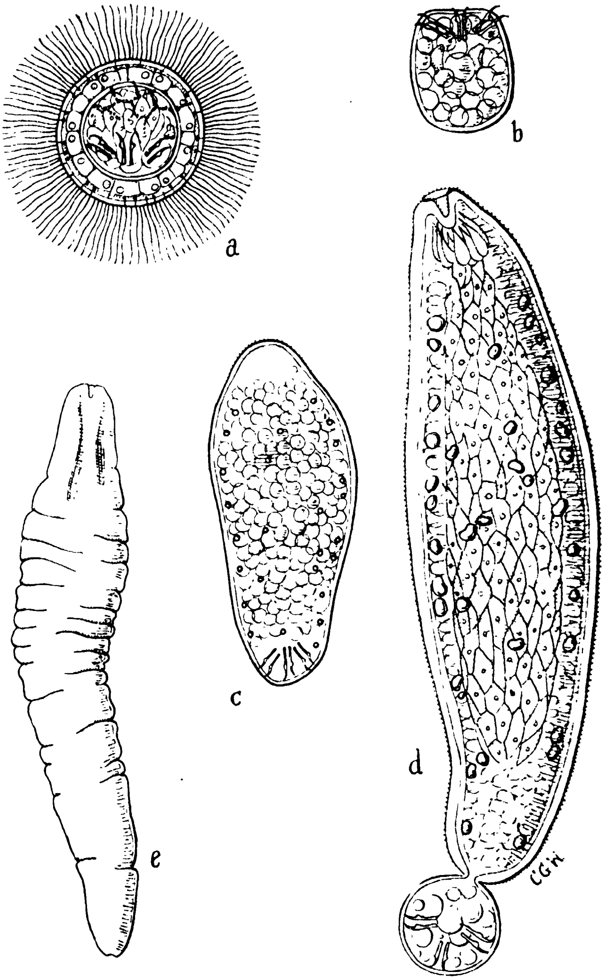

FIG. 48.—*Diphyllobothrium latum*, DEVELOPMENTAL STAGES. (FROM FUHRMANN IN KÜKENTHAL, AFTER ROSEN.)

a, Coracidium; *b*, onchosphere from body cavity of *Cyclops*, 5 days after passage through intestinal wall; *c*, young procercoid from body cavity of *Cyclops*; *d*, mature procercoid; *e*, young plerocercoid from body-cavity of pike.

Sparganum Diesing, 1845

This is a name applied to larval forms of the *Diphyllobothriidæ*, which are found in connective tissue in various animals. They are variable in form, ribbon-like or irregularly branching and may multiply by budding.

Some of them have been fed to dogs and raised to the adult stage, *e.g.* *S. raillieti* v. Ratz, 1912, which occurs in the pig.*

Several other species of *Diphyllobothrium* have been described from dogs and other animals, but they are relatively rare, and it is possible that some of them are identical. *D. mansoni* is not infrequent in the dog, cat and wild carnivora in China. The procercoid develops in a *Cyclops* and the *Sparganum* in frogs, snakes and man.

Order CYCLOPHYLLIDEA

Family MESOCESTOIDIDÆ

This family is characterised by the presence of four suckers, the absence of a rostellum and hooks and the median position of the genital pore. The eggs become enclosed in a thick-walled par-uterine capsule.

Genus Mesocestoides Vaillant, 1863

M. lineatus (Goeze, 1782) occurs in the small intestine of the dog, cat, fox, beech marten, mink and wild carnivores. The scolex is large and the suckers are elongate oval. The worm is 30-250 cm. long and has a maximum width of 3 mm. The mature segments contain each a single set of reproductive organs. The cirrus-sac and the vagina open close together near the mid-line on the ventral surface. There are about

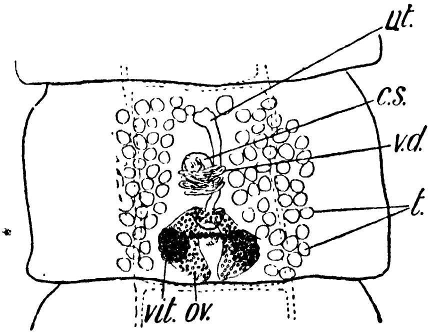

FIG. 49.—*Mesocestoides lineatus*, MATURE SEGMENT, DORSAL VIEW. (AFTER BAYLIS.)

c.s., Cirrus-sac; *ov.*, ovary; *t.*, testes; *ut.*, uterus; *v.d.*, vas deferens; *vit.*, vitellarium.

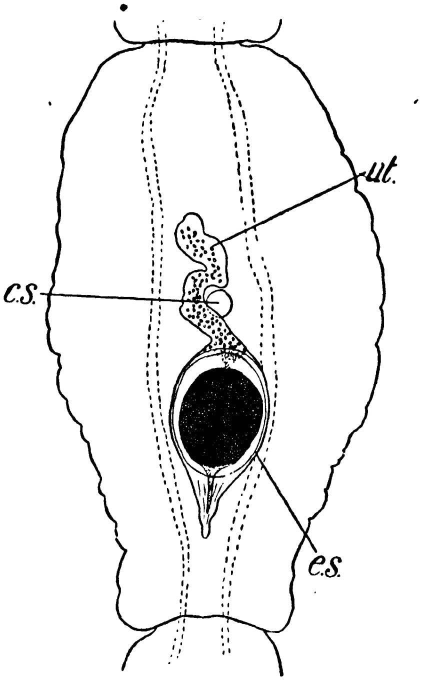

FIG. 50.—*Mesocestoides lineatus*, GRAVID SEGMENT, DORSAL VIEW. (AFTER BAYLIS.)

c.s., Cirrus-sac; *e.s.*, egg-sac; *ut.*, uterus.

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* Kotlán, *Centralbl. f. Bact.*, I, Orig. 90 (4): 272-285. 1928.

50 testes, lying on either side of the longitudinal excretory canals. The ovary and the vitelline gland are bilobed and posterior in position. The eggs are oval and measure 40-60 by 35-43 μ.

Life-Cycle.—For some time the larval form known as a Dithyridium has been suspected to be the intermediate stage of worms of the genus *Mesocestoides* on account of the shape of the scolex. The intermediate stage of *M. lineatus* is not known, but Schwartz has fed a Dithyridium from the lungs and peritoneal cavity of a mongoose to a dog and raised a species of this genus, thus proving the suspected relationship of these organisms.

Pathogenicity, etc.—See p. 102.

Dithyridium variabile (Diesing, 1850) is a larval form which occurs in small cysts under the skin of the fowl, turkey and wild birds.

Family ANOPLOCEPHALIDÆ

The worms of this family have neither rostellum nor hooks. The proglottides are usually wider than long and have each one or two sets of genital organs. The genital pores are marginal. The testes are usually numerous. The uterus may persist or be replaced by egg-capsules, or the eggs may pass into one or more par-uterine organs. The embryonic egg-shell is frequently pear-shaped, bearing on one side a pair of hooked projections, and is then known as a "pyriform apparatus." The intermediate hosts, as far as known, are mites of the family *Oribatidæ*.

Genus **Anoplocephala** E. Blanchard, 1848

A. magna (Abildgaard, 1789) occurs in the small intestine and rarely in the stomach of equines. It measures up to 80 cm. in length and 2 cm. wide. The scolex is large, 4-6 mm. wide, with suckers opening anteriorly. There is usually a short neck and the segments are very short. The genital organs are single and the pores are unilateral. The main stem of the uterus is transverse, with anterior and posterior branches. The eggs have a pyriform apparatus and measure 50-60 μ.

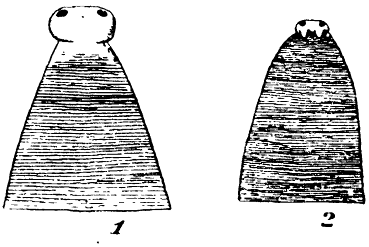

FIG. 51.—1, *Anoplocephala magna*, ANTERIOR END; 2, *A. perfoliata*, ANTERIOR END. (AFTER MÖNNIG.)

A. perfoliata (Goeze, 1782) occurs in the small and large intestine of equines. It measures up to 8 by 1·2 cm. It differs from the preceding species in having a smaller head, 2-3 mm. in diameter, provided with a small lappet behind each sucker, while the segments are exceedingly short. The eggs measure 65-80 μ.

Genus **Paranoplocephala** Lühe, 1910

P. mamillana (Mehlis, 1831) occurs in the small intestine and occasionally the stomach of the horse. It measures only 6-50 by 4-6 mm. The openings of the suckers are slit-like and situated dorsally and ventrally. The eggs measure about 51 by 37 μ.

Life-Cycle.—The intermediate hosts are oribatid mites.

Pathogenicity and Symptoms.—Light infections of tapeworms in horses produce no symptoms, but larger numbers of worms cause digestive disturbances, unthriftiness, a shaggy coat and even anæmia. *A. perfoliata* produces small inflamed areas and ulcers of the mucosa where it attaches itself, and, in severe cases, the fæces are covered with blood-stained mucus. This species has also been known to cause rupture of the cæcum.

Diagnosis can be made by finding the ripe proglottides or eggs in the fæces.

Treatment.—Very little definite information has been gathered on this subject. The following is frequently employed: 60 c.c. turpentine and 4 c.c. male-fern extract in 1 litre raw linseed oil for an adult horse, after starving the animal for 24-36 hours. Kamala in a dose of 30 gm., or 30-45 gm. of freshly ground areca nut, both without a purgative, may be useful. All these drugs should be used with the necessary caution.

Genus **Moniezia** R. Blanchard, 1891

M. expansa (Rudolphi, 1810) occurs in the small intestine of sheep, goat, cattle and several other ruminants in most parts of the world. It may reach a length of 600 cm. and a width of 1·6 cm. The scolex is 0·36-0·8 mm. wide, with prominent suckers. The segments are broader than long and each contains two sets of genital organs. The ovaries and the vitelline glands form a ring on either side, median to the longitudinal excretory canals, while the testes are distributed throughout the central field or they may be concentrated towards the sides. At its posterior border each proglottis contains a row of interproglottidal glands, arranged around small pits. The two uteri form together a reticular network in the ripe segment. The eggs are somewhat triangular in shape, containing a well-developed pyriform apparatus, and measure 56-67 μ in diameter.

M. benedeni (Moniez, 1879) occurs in ruminants, like the preceding species, from which it differs mainly in being broader (up to 2·6 cm.), and in having the interproglottidal glands arranged in a short, continuous row close to the mid-line of the segment.

Life-Cycle.—Stunkard and others found that, when mites of the genus *Galumna* and *Scheloribates* ingest the eggs of *M. expansa*, these hatch in the intestine and the cysticercoids develop in the body cavity of the mite in 2-5 months. Lambs become infected very early in life and may pass ripe segments when they are 6 weeks old. The worms apparently do not live longer than about 3 months in the host.

Pathogenicity and Symptoms.—As a rule only lambs, kids and calves under 6 months of age become infected and show symptoms, but adult animals occasionally also harbour the parasite. Heavy infections are common, but even one or a few worms are able to produce disease on account of their large size. On the other hand, some authors maintain that these parasites are hardly pathogenic. These differences may be due to factors which influence the resistance of the animal, such as the quantity of milk given by the mother, climatic conditions, etc.

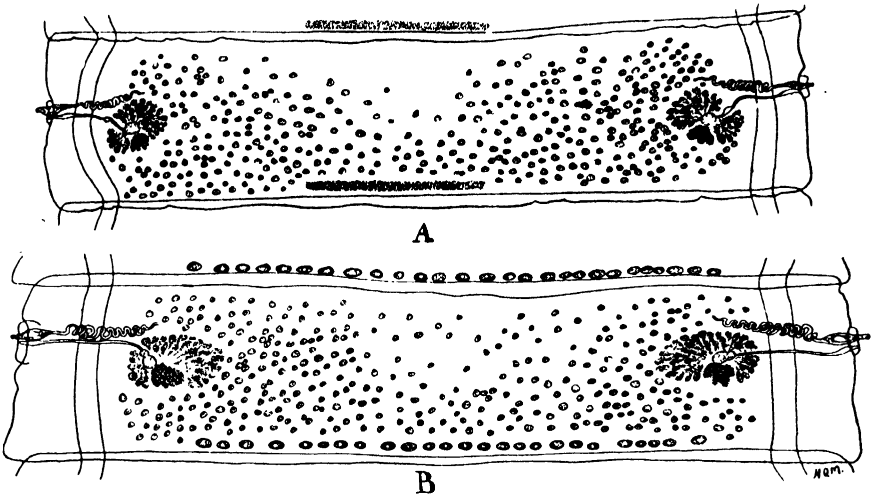

FIG. 52.—A, *Moniezia benedeni*, MATURE SEGMENT; B, *M. expansa*, MATURE SEGMENT. (ORIGINAL.)

The pathogenesis is not quite clear, but the rapid growth of the worms and the prolific production of ripe segments indicate that much nourishment is required and obtained from the lamb, and that a large quantity of waste products must be eliminated by the parasite. These are probably absorbed to a fair degree and cause intoxication.

The affected young animals show loss of vigour and strength and have a rough coat. They become stunted and markedly pot-bellied. Anæmia and consequent œdemas may develop. Constipation may sometimes be seen and diarrhœa occurs in severe cases. Frequently a chain of segments is seen to hang out through the anus. Rare cases of infection in adult animals with paretic or other nervous symptoms have been described.

Post-Mortem.—Poverty, a distended abdomen and pale mucous membranes are the main external features. Anæmia, sometimes cachexia, and dropsy are present. The liver may show fatty changes. In the small intestine the parasites are found and they can be recognised by the double set of genital organs in each segment. The heads are rarely attached to the mucosa. The latter may be thickened. It is often noticed that fragmentation of the worm occurs after death of the host.

Diagnosis.—The pot-bellied and stunted appearance and the presence in the fæces of ripe segments, which resemble cooked rice grains and from which *Moniezia* eggs can be identified, indicate the presence of tapeworms.

Treatment.—Kamala is recommended in doses of 4 gm. for lambs, but is liable to cause excessive purgation. Male-fern extract is good when fresh, but is expensive. The following mixture has been used on a large scale and gives very fair results, also being effective against other worms: 40 per cent. nicotine tobacco extract 30 c.c., copper sulphate 30 gm., soft water 1,800 c.c. The dose for lambs and kids is 15-45 c.c.; for calves 30 c.c. per 22·5 kilo (50 lbs.) live weight, with a maximum of 100 c.c., followed by a dose of castor oil after ½ hour. The animals should be dosed on an empty stomach in the morning and starved for another 2 hours, otherwise absorption of the drugs takes place and poisoning may result. The nodular worm remedy (p. 179) used in South Africa has been found to be very effective. An emulsion of tetrachlorethylene gives good results. McCulloch and McCoy (1941) report good results with 0·5 gm. lead arsenate in a gelatine capsule for lambs. Whichever remedy is used, it has been found that it is desirable to make a change periodically, since drug-resistant strains of the worms seem to develop. Phenothiazine is ineffective. In heavily infected areas the animals should be treated from 3 weeks old, and the treatment repeated every 3 weeks.

Prophylaxis.—The regular treatment of infected animals is important to reduce the infection. The oribatid mites shun light and dry conditions. They are consequently found mostly in moist pastures and where the grass is long, and are active early in the morning and towards sunset. These facts may indicate preventive measures. The mites do not fly, so that infection is spread by the final hosts.

Genus **Cittotænia** Riehm, 1881

C. ctenoides (Railliet, 1890) occurs in the small intestine of the rabbit in Europe. It may grow up to 80 cm. long and 1 cm. wide. The scolex is about 0·5 mm. broad. A short neck is present. The proglottides are all much broader than long and each contains two sets of genital organs. The genital pores are situated in the posterior quarters of the proglottides. On either side there is a group of 60-80 testes behind the ovary. The cirrus pouch is 0·2 mm. long. The eggs have a pyriform apparatus and measure about 64 μ in diameter.

C. denticulata (Rudolphi, 1804) occurs in the rabbit in Europe. It has no neck and the scolex measures 0·8 mm. in diameter.

C. pectinata (Goeze, 1782) occurs in hares and rabbits in Europe, Asia and America. Its scolex is about 0·25 mm. in diameter and a neck is present.

Life-Cycle.—The intermediate hosts are oribatid mites.

Pathogenicity.—Heavy infections of these tapeworms, especially *C. ctenoides*, frequently cause digestive disturbances, emaciation and even death amongst rabbits.

Treatment.—Male-fern extract at the rate of 0·3 gm. per kilo body-weight is effective.

Genus **Avitellina** Gough, 1911

Several species of this genus have been described and the question of their identity is not definitely settled. They occur in the small intestine of sheep, goats, cattle and other ruminants in Africa, Italy and India. They are 3 m. long or longer and about 3 mm. wide. The scolex measures up to 2 mm. in diameter. The proglottides are very short and not well marked, so that the worm appears macroscopically to be unsegmented. Posteriorly there is a median opaque line formed by the uterus and eggs, while the wide excretory canals on either side show as transparent lines. The ripe portion of the body is narrow and almost cylindrical. The genital organs are single and the pores irregularly alternating. There are groups of testes on either side of the excretory canals. Vitelline glands are absent. The eggs in the ripe segments pass into large thick-walled par-uterine organs, one to each segment. They have no pyriform apparatus.

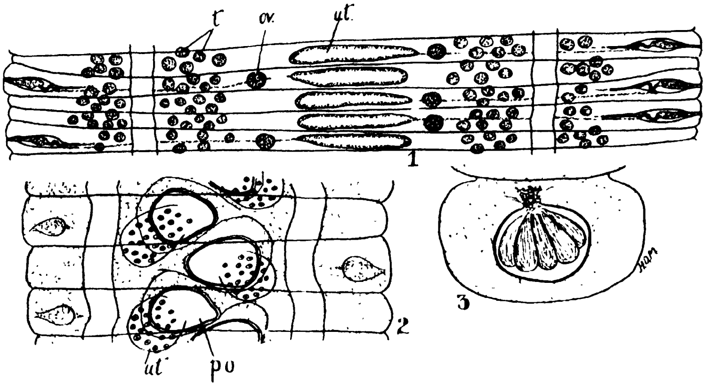

FIG. 53.—*Avitellina centripunctata:* 1, MATURE PROGLOTTIDES; 2, GRAVID PROGLOTTIDES, EGGS PASSING INTO PAR-UTERINE ORGANS; 3, "RIPE" PROGLOTTIS, PAR-UTERINE ORGAN WITH EGGS IN BUNCHES. (ORIGINAL.)

ov., Ovary; *p.o.*, par-uterine organ; *t.*, testes; *ut.*, uterus.

Pathogenicity.—These tapeworms are not as pathogenic as the Moniezias, but they sometimes occur in very heavy infections and may then produce marked symptoms. They occur more frequently in adult animals than the Moniezias.

Treatment.—As for *Moniezia.*

Genus **Stilesia** Railliet, 1893

S. hepatica Wolffhügel, 1903, occurs in the bile ducts of sheep, goat, cattle and wild ruminants in Africa and is very common in certain parts. Complete specimens are rarely obtained, as the parasites creep into the fine bile ducts and the strobila breaks easily. They are about 20-50 cm. long and up to 2 mm. wide. The scolex is large, with prominent suckers, and is often followed by a broad neck about 2 mm. long. The segments are short but usually well visible. The genital organs are single. There are about 11 testes on either side, mainly median to the excretory canals. Vitelline glands are absent. Each segment forms two par-uterine organs. The eggs have no pyriform apparatus.

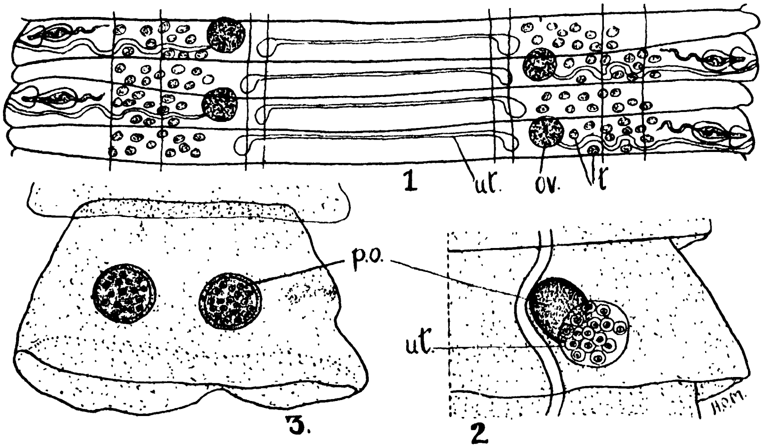

FIG. 54.—*Stilesia hepatica:* 1, MATURE PROGLOTTIDES; 2, HALF OF GRAVID PROGLOTTIS, EGGS PASSING INTO PAR-UTERINE ORGAN; 3, "RIPE" PROGLOTTIS, EGGS IN PAR-UTERINE ORGANS. (ORIGINAL.)

ov., Ovary; *p.o.*, par-uterine organ; *t.*, testes; *ut.*, uterus.

Pathogenicity.—*Stilesia hepatica* occurs in animals of all ages. It is practically non-pathogenic. Cases of extremely heavy infections are often seen in perfectly healthy sheep. Although the bile ducts may be practically occluded, or even form sac-like dilatations filled with the worms, no icterus or other symptoms are seen. In affected livers there may be slight cirrhosis and the walls of the bile ducts are usually thickened. Such livers have to be condemned at meat inspection, and this is the only practical significance of the parasite.

An interesting question is the origin of the food supply of this **worm.** Since it has no alimentary canal it cannot suck blood, but has to absorb its nourishment from the bile in which it lies. The normal bile, however, does not contain much that would be useful to the worm. Probably the liver is stimulated to excrete certain substances on which the parasite lives.

S. globipunctata (Rivolta, 1874) occurs in the small intestine of the sheep and goat in Europe and India. It is 45-60 cm. long and up to 2·5 mm. wide. It has 4-7 testes on either side, lateral to the excretory canals.

Genus Thysanosoma Diesing, 1835

T. actinioides Diesing, 1835, the "fringed tapeworm," occurs in the bile ducts, pancreatic ducts and small intestine of sheep, cattle and deer in America, especially the western parts of the United States. It measures 15-30 cm. by 8 mm. The scolex is up to 1·5 mm. wide. The segments are short and conspicuously fringed posteriorly. Each segment contains two sets of genital organs and the testes lie in the median field. Several par-uterine organs are formed in each segment and the eggs have no pyriform apparatus.

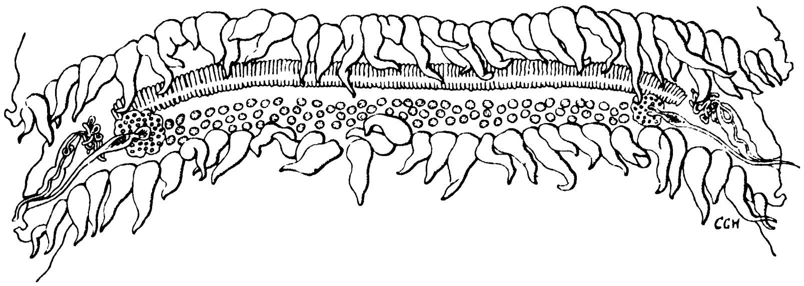

FIG. 55.—*Thysanosoma actinioides*, MATURE PROGLOTTIS. (AFTER FUHRMANN IN KÜKENTHAL.)

Pathogenicity and Symptoms.—The pathogenicity of this parasite has apparently formerly been over-estimated, as the symptoms of loco poisoning and other diseases have been ascribed to it, according to Christenson. It may partly obstruct the flow of bile and pancreatic juice and cause digestive disorders and unthriftiness. Such affected sheep are liable to die under adverse conditions.

Diagnosis is made by finding the ripe segments and eggs in the fæces.

Treatment.—The parasites in the intestine can be killed by means of the drugs recommended for *Moniezia*, but for the more important ones in the bile and pancreatic ducts no remedy is known, all drugs tested so far having failed.

Prophylaxis.—As in the case of *Moniezia.*

Genus **Thysaniezia** Skrjabin, 1926

T. giardi (Moniez, 1879) occurs in the small intestine of sheep, goat and cattle in Europe, Africa and America. It grows to about 200 cm. long and 12 mm. wide, the width varying greatly in different specimens. The scolex is often small, but may measure over 1 mm. in diameter. The segments are short and each contains a single set of genital organs, very rarely two, the pores alternating irregularly. The testes are lateral to the excretory canals. The side of the segment which contains the cirrus-sac bulges out, thus giving the margin of the worm an irregular appearance. The eggs, which are devoid of a pyriform apparatus, pass from the uterus into a large number of small par-uterine organs. The ripe segments found in the fæces are therefore easily distinguishable from those of *Moniezia*.

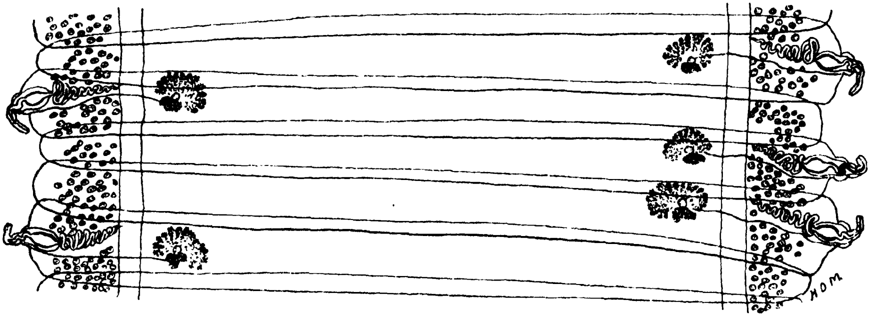

Fig. 56.—*Helictometra giardi*, Mature Proglottides. (Original.)

Life-Cycle.—The intermediate hosts are oribatid mites.

Pathogenicity.—This worm occurs in young and adult animals, but is rarely seen in numbers sufficiently large to produce symptoms. It is the most frequent tapeworm of adult cattle in South Africa.

Treatment and Prevention.—As in the case of *Moniezia*.

An unidentified Anoplocephalid is mentioned by Sprehn as being very pathogenic to the coypu. For treatment, this author recommends male-fern extract, 0·3 gm. per kilo bodyweight.

Family Davaineidæ

These cestodes are characterised by the presence on the rostellum of numerous small, hammer-shaped hooks. The suckers are usually also provided with hooks. Genital organs usually single. The eggs may pass into egg-capsules or into a par-uterine organ, or the uterus may persist. Parasites of birds chiefly.

Genus **Davainea** Blanchard, 1891

D. proglottina (Davaine, 1860) occurs in the duodenal loop of the small intestine of the fowl, pigeon and other gallinaceous birds in most parts of the world. It has only 4-9 proglottides and is 0·5-3 mm. long. The rostellum bears 80-94 hooks, 7-8 μ long, and the suckers have a few rows of small hooks which are easily lost. The genital pores are regularly alternating. The eggs lie singly in the parenchyma of the ripe segments.

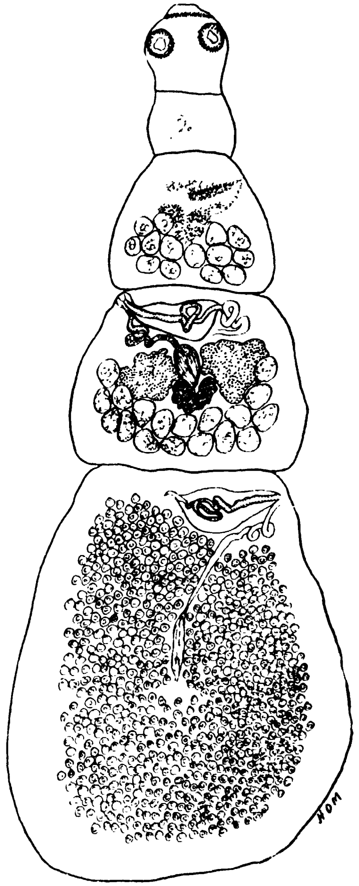

FIG. 57. — *Davainea proglottina*, COMPLETE SPECIMEN. (ORIGINAL.)

Life-Cycle. — The ripe segments are passed in the fæces and the eggs hatch after having been swallowed by slugs of the genera *Limax*, *Arion*, *Cepæa* and *Agriolimax*, in which the embryo develops into a cysticercoid in about 3 weeks during the summer. Fowls become infected by ingesting the infected slugs. The adult stage is reached in the fowl in about 14 days. The onchospheres remain viable for about 5 days in moist surroundings, but are rapidly killed by frost and drying. According to Wetzel* the ripe proglottides are positively phototropic and climb up moist grass-blades, where they are eaten by the slugs.

Pathogenicity, etc.—See p. 108.

✓*Genus* **Raillietina** Fuhrmann, 1920

This genus has been divided into several subgenera by Fuhrmann. In the subgenus *Raillietina* the genital pores are unilateral and the egg-capsules each contain several eggs.

R. (R.) tetragona (Molin, 1858) occurs in the small intestine of the fowl, guinea-fowl, pigeon and pea-fowl, and is cosmopolitan in distribution. It is one of the largest of the fowl tapeworms, measuring up to 25 cm. in length. It has a long, thin neck and a small scolex with 100 minute hooks, 6-8 μ long, in one row on the rostellum. The suckers are oval in shape and armed with 8-10 rows of small hooks, which may be lost. The egg-capsules each contain 6-12 eggs and extend laterally to the excretory vessels. This species is difficult to distinguish from *R. echinobothrida.* The oval shape of the suckers and the weaker armature of the scolex are conspicuous when the two worms are compared to each other.

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* *Arch. f. wiss. u. pr. Tierheilk.*, 65 (6): 595-625. 1932.

Life-Cycle.—The intermediate hosts are ants of the genera *Tetramorium* and *Pheidole.*

Pathogenicity, etc.—See p. 108.

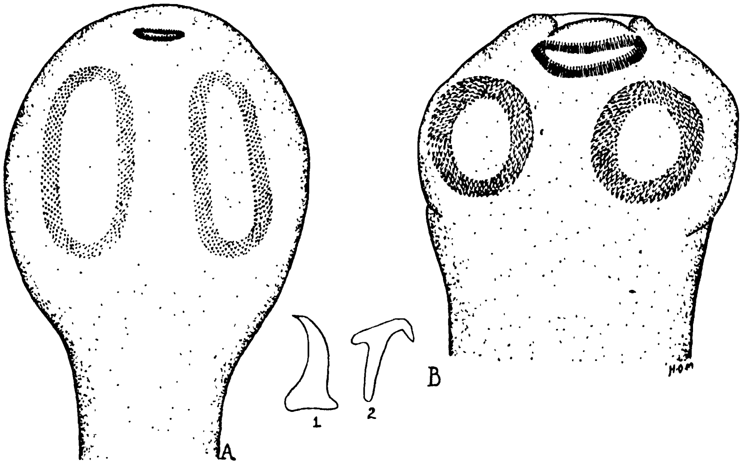

FIG. 58.—A, *Raillietina tetragona*, SCOLEX ; B, *R. echinobothrida*, SCOLEX. 1, HOOK FROM SUCKER; 2, HOOK FROM ROSTELLUM OF B. (ORIGINAL.)

R. (R.) echinobothrida (Megnin, 1880) occurs in the small intestine of the fowl in most parts of the world. In shape and size it resembles *R. tetragona.* The rostellum bears 200 hooks, 10-13 μ long, in two rows, and the suckers are armed with 8-10 rows of hooks, all of which are about twice as large as those of the latter species, and the scolex has the appearance of being more heavily armed, while the suckers are circular in outline. The genital pores are as a rule unilateral, but in occasional specimens they are alternating. The gravid segments frequently separate at the middle, forming small windows in the posterior part of the worm.

Life-Cycle.—Jones and Horsfall found that the intermediate host is an ant, *Tetramorium cæspitum,* which is cosmopolitan in distribution and has such varied feeding and nesting habits* that its control may be difficult. Artificially infected birds passed the first ripe segments after 19-20 days. Other intermediate hosts are the ants *T. semilæve* and *Pheidole* sp.

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* Horsfall, 1938, *Journ. Par.*, 24 (5): 409, gives particulars on the habits of these ants.

Pathogenicity, etc.—See p. 108.

In the sub-genus *Skrjabinia* the genital pores alternate irregularly and the egg-capsules usually contain one egg each.

R. (S.) cesticillus (Molin, 1858) occurs in the small intestine of the fowl, guinea-fowl and turkey, and is cosmopolitan in distribution. It may grow up to 13 cm., but is usually not much over 4 cm. long. The worm is easily recognised by the absence of a neck and the large scolex which bears a wide rostellum, armed with 400-500 small hooks. The suckers are inconspicuous and unarmed.

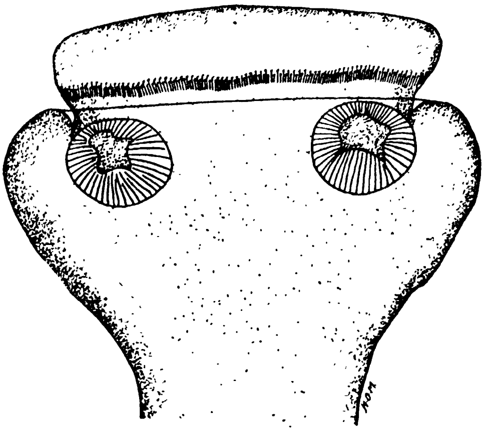

FIG. 59.—*Raillietina cesticillus*, SCOLEX. (ORIGINAL.)

Life-Cycle.—The intermediate hosts are numerous kinds of beetles. Development in the fowl takes 19-20 days.

Pathogenicity, etc.—See p. 108.

Quite a number of other species of this genus are known from domestic birds, but are not very common.

Genus Cotugnia Diamare, 1893

C. digonopora (Pasquale, 1890) occurs in the small intestine of the fowl in Europe, Africa and Asia. It is up to 107 mm. long. Like the other species of this genus, it has two sets of genital organs in each segment. The rostellum bears two rows of small hooks and the suckers are unarmed.

Life-cycle unknown.

Pathogenicity, etc.—See p. 108.

C. fastigata Meggit, 1920, occurs in the duck in Burma and **C. cuneata** Meggit, 1924, in the pigeon in Burma and India.

Genus Houttuynia Fuhrmann, 1920

H. struthionis (Houttuyn, 1773) occurs in the small intestine of the ostrich. Several species of this genus have been described from the ostrich, but they are all identical, according to Baer. The worms grow up to 60 cm. long and 9 mm. wide. The scolex is 1-2 mm. wide and bears a double row of about 160 large and small hooks. The large hooks are 0·077 mm. long and the small ones 0·063 mm. The genital pores are unilateral. In the gravid segments the eggs are contained in parenchymatous capsules, about 15-25 in each.

Life-cycle unknown.

Pathogenicity and Symptoms.—The parasite is seen especially in ostrich chicks, causing unthriftiness, emaciation and sometimes diarrhœa. The affected chicks are inactive, lose their appetite and often die. Numerous chicks may be lost where the infection is severe. The adult birds are frequently carriers of the infection, but rarely show any symptoms.

Diagnosis is made from the symptoms and the presence of the ripe segments in the droppings.

Treatment.—No very satisfactory remedy is known, but kamala or carbon tetrachloride would be indicated.

Prophylaxis. — Since the intermediate host is not known, no definite recommendations can be made. It has, however, been found expedient in practice to raise the chicks in runs planted with lucerne as far away as possible from the adult birds. When the chicks have to run with the hen, the paddock should be cleaned of droppings daily and all insects, like ants, should be exterminated.

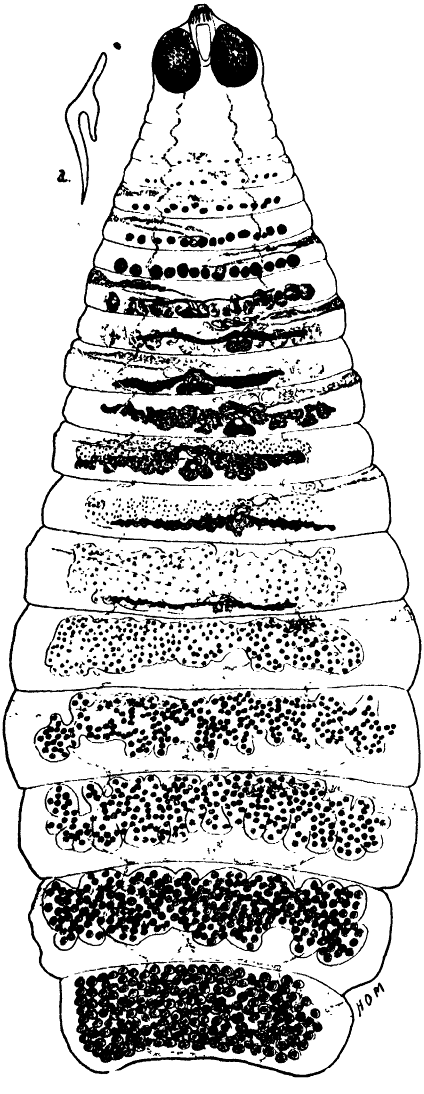

FIG. 60.—*Amœbotænia sphenoides*, COMPLETE SPECIMEN. (AFTER MÖNNIG.) *a*, Rostellar hook, much enlarged.

Family DILEPIDIDÆ

In this family the rostellum is usually provided with hooks, but the suckers are unarmed. Genital organs single or double. The testes are numerous. The uterus may be sac-like or branched and persist or the eggs pass into parenchymatous capsules or par-uterine organs.

Genus **Amœbotænia** Cohn, 1899

A. sphenoides (Railliet, 1892) occurs in the small intestine of the fowl in most parts of the world. It is a small worm with an elongate, triangular shape, rarely over 4 mm. long and 1 mm. wide. The rostellum bears 12-14 hooks with a characteristic shape and there are about 20 proglottides. The testes are 12 or more in number and lie near the posterior border of the segment. The uterus is sac-like and slightly lobed.

Life-Cycle.—The intermediate hosts are earthworms of various species, in which the cysticercoid develops in about 14 days. Fowls acquire the infection frequently after rains when the earthworms come to the surface. The worms grow adult in the fowl in 4 weeks.

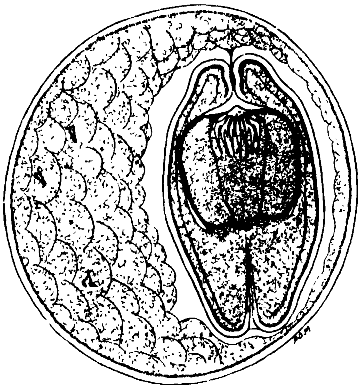

Fig. 61.—*Amœbotænia sphenoides*, Mature Cysticercoid. (After Mönnig.)

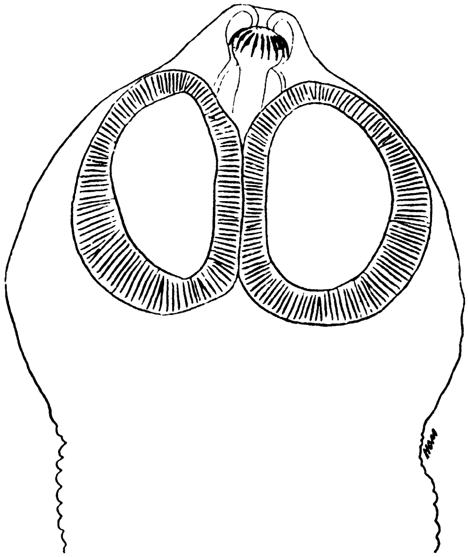

Fig. 62.—*Choanotænia infundibulum*, Scolex. (Original.)

Pathogenicity and Symptoms.—See below.

Genus **Choanotænia** Railliet, 1896

C. infundibulum (Bloch, 1779) occurs in the small intestine of the fowl and turkey. It is up to 20 cm. long and the segments are markedly wider posteriorly than anteriorly, giving the worm a characteristic shape. The scolex bears 16-20 slender hooks. The genital pores alternate irregularly and open near to the anterior border of the segment. There are 25-60 testes, situated posteriorly. The uterus is persistent and strongly lobed.

Life-Cycle.—The intermediate hosts are the house fly, *Musca domestica*, and the beetles *Geotrupes sylvaticus*, *Aphodius* sp., *Calathus* sp. and *Triboleum.*

TÆNIASIS IN POULTRY

Pathogenicity and Pathogenesis.—The pathogenicity of tapeworms to poultry appears to depend very much on the state of nutrition, the age and the general condition of the birds. The different species of tapeworms of poultry vary greatly in pathogenicity. *Davainea proglottina*, although it is the smallest, is the most harmful. It penetrates deeply into the mucosa and produces a marked enteritis, which is frequently hæmorrhagic in heavy infections. *Raillietina tetragona* and *R. echinobothrida* follow next in order of pathogenicity. The young worms of the latter species penetrate with their anterior ends deeply into the mucosa and submucosa of the duodenum, causing the formation of nodules, which must be differentiated from tubercular nodules. They are visible from the peritoneal surface and contain necrotic tissue and leucocytes. During the early stages the young worms can be found hanging out into the lumen of the gut. Later the adult parasites are found in the posterior part of the small intestine. The other species are not very harmful unless the infection is severe, when marked symptoms may be produced. *Amœbotænia sphenoides* is practically harmless under normal conditions, but it will aggravate the symptoms caused by any factor which affects the general health of the birds; for instance, bad feeding or any disease. Under such conditions these worms may cause enteritis, rapid wasting and death.

Symptoms.—Young birds are most frequently affected. They show loss of appetite, droopiness, usually thirst, emaciation and anæmia. In the case of laying birds egg-production is decreased or suspended. Light infections predispose to other diseases like roup, while more severe infections frequently cause death. *Davainea proglottina* causes diarrhœa, the fæces being discoloured by blood pigments. This species and sometimes also others are often the cause of paretic symptoms, the legs especially being involved.

Diagnosis.—In the case of poultry it is usual to kill a bird and make a diagnosis at autopsy. The symptoms and the presence of large numbers of tapeworm segments or eggs in the fæces will indicate the cause of the disease, but it is desirable that a specific diagnosis should be made in connection with preventive measures, and this can be done most satisfactorily by finding the worms at autopsy. If there are paretic symptoms, neurolymphomatosis and other causes must be excluded. A daily rhythm in the production of ripe segments has been noted in the case of *Davainea proglottina* and *Raillietina cesticillus*, the majority of segments being passed in the early part of the afternoon.

Post-Mortem.—Besides emaciation and anæmia there may be enteritis, varying in degree with the species of parasite and the severity of the infection. The mucosa may be thickened and hæmorrhagic. The small species are not easily seen, and it is advisable to make a routine procedure of scraping the mucosa of the duodenum into a large glass dish containing a small quantity of water, in which the worms can then be found. They may be present in very large numbers.

Treatment.—The following drugs are the most effective, but repeated treatments may be necessary in the case of *Davainea proglottina*: Kamala in 1 gm. doses for fowls and 2 gm. for adult turkeys, administered in a bread pill or capsule, after starving overnight. This drug has a purgative action, and is, therefore, not given with a purgative. Carbon tetrachloride, 1-2 c.c. for fowls, administered as described under *Echinostoma revolutum.* Both these drugs are well tolerated by birds, but in case of enteritis, or when other diseases are present, treatment is not advisable and discretion must be used. On the whole treatment against tapeworms in birds is not very effective, because the heads are not removed. It would therefore be indicated only where it is desirable to relieve young birds of a massive infection, which they may then be able to overcome by gaining strength. Reid found that 24 hours' starvation of the birds weakened the tapeworms to such an extent that many were expelled automatically.

Prophylaxis.—As the life-cycles of the parasites indicate, birds on free range are more liable to become infected than those that are kept in pens. The converse is true in the case of most roundworms of poultry, and these facts have to be taken into account in deciding on the system to be adopted. As far as possible the intermediate hosts, especially slugs and snails, should be exterminated.

Genus **Dipylidium** Leuckart, 1863

D. caninum (Linnæus, 1758) occurs in the small intestine of the dog, cat, fox, and occasionally in man. It has a world-wide distribution, and is the commonest tapeworm of dogs in most parts of the world. The parasite may be up to 50 cm. long, and usually has a light reddish-yellow colour. The mature, and even more the gravid, proglottides have a characteristic elongate, oval shape, resembling cucumber seeds. The rostellum bears several rows of small, rose-thorn-shaped hooks. In *D. caninum*, as described by some authors, there are three to four rows of hooks. This species, however, appears to be very variable, and several or all (according to Witenberg) of the dozen odd species described are identical. The hooks are so placed on the rostellum that it is frequently possible to count either four or up to seven rows. Each segment contains two sets of genital organs. The numerous testes are distributed throughout the medullary parenchyma. The ovaries and vitelline gland form a mass on either side, resembling a bunch of grapes in shape. In the gravid segments the eggs lie in egg-capsules, each containing up to twenty eggs.

Life-Cycle.—The ripe segments are voided with the fæces or they may leave the host spontaneously, as do those of some other cestodes. In the latter case the segment may crawl about actively, disseminating its eggs as it moves along. The intermediate hosts are the dog flea, *Ctenocephalides canis*, the cat flea, *C. felis*, and the human flea, *Pulex irritans*, while the dog louse, *Trichodectes canis*, has also been incriminated. The larval stages of the fleas become infected by swallowing the eggs, and the cysticercoids develop in them after the fleas have reached the adult stage. The final host acquires the parasite by swallowing the infected flea, while the human cases, which occur mainly in young children, are probably due to the accidental ingestion of such fleas when the children play with dogs or cats.

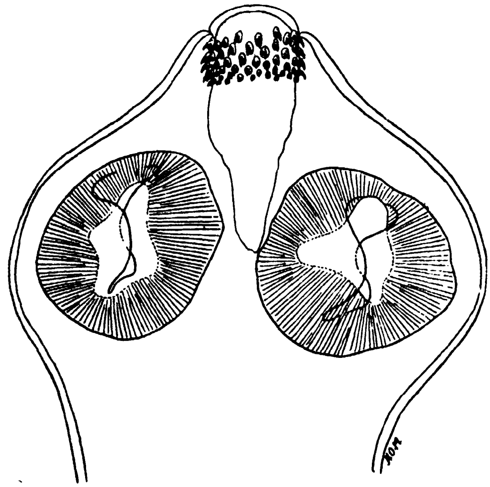

FIG. 63.—*Dipylidium caninum*, SCOLEX. (ORIGINAL.)

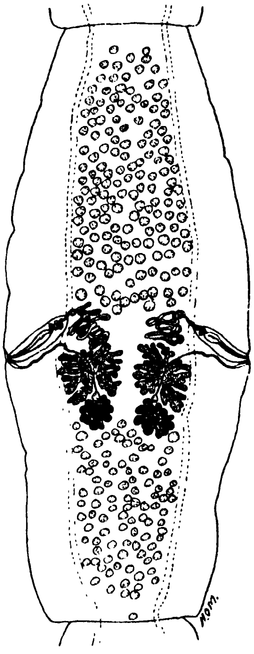

FIG. 64.—*Dipylidium caninum*, MATURE PROGLOTTIS. (ORIGINAL.)

TÆNIASIS IN DOGS AND CATS

Pathogenesis and Symptoms.—The pathogenicity of the various species concerned varies, the larger being as a rule more pathogenic than the smaller ones; but the severity of the infection is usually of greater importance, as well as the age of the host.

In general, cestodes are not very harmful to dogs and cats. Sometimes, however, symptoms of colic or of chronic enteritis are seen. The animals may become voracious or, in other cases, the appetite is diminished. Unthriftiness, a shaggy coat and emaciation are frequent. Dogs often show symptoms of irritation in the abdomen by rolling or rubbing the abdomen on the ground, or by biting at it. Convulsions and epileptiform fits may occur and are not infrequent in the case of cats. Nervous symptoms resembling those of rabies have been recorded, and this fact should be borne in mind, although such symptoms are more usually associated with infections of nematodes or acanthocephala. Ripe segments occurring in the rectum frequently produce irritation in dogs and rarely also in cats, causing the animal to take up a sitting attitude and to draw the anus over the ground. This characteristic symptom is frequently the first that is noticed by the owner.

Post-Mortem.—Emaciation is usually found and cases of intussusception due to cestodes have been described. Varying degrees of enteritis may be present, from a catarrh to a croupous or hæmorrhagic enteritis, especially in heavy infections of *Echinococcus granulosus*. *Dipylidium* may destroy the mucosa by means of its suckers and embed its head deeply in the tissues. The worms are found in the small intestine or they may have migrated to the stomach or colon after death. Sometimes they form masses occluding the lumen of the gut. Penetration of the intestinal wall is very rare. In human cases of perforation by Tænias, the worms appear to be attracted towards the kidneys, and they have even been found in the pelvis of that organ.

Diagnosis.—The symptoms usually have to be differentiated from those of other intestinal disorders or diseases affecting the nervous system. This can be done by finding the proglottides in the fæces and making a specific diagnosis from them as far as possible.

Treatment.—For dogs the usual drug employed is arecoline hydrobromide in doses of 2 mg. per kilo bodyweight (a total of $\frac{1}{16}$-$\frac{1}{2}$ grain). The drug frequently causes vomiting, and is therefore best given in a gelatin capsule, together with a diluent such as sugar, 4 hours after a feed. Care should be taken that there is no constipation at the time of treatment. After administration of the drug, the dog is best taken on a leash and allowed to run. Under such conditions the worms are passed in about 10-20 minutes. They should be collected and destroyed, since the posterior portion of the body consists of gravid segments which contain numerous infective eggs.

Kamala may be given to dogs in doses of 2-6 gm., but is more usually employed for the treatment of cats, giving $\frac{1}{2}$-1 gm. in a small quantity of fish such as sardines or salmon, as these animals do not tolerate arecoline hydrobromide very well. In the case of dogs in poor condition or in case of enteritis, when arecoline hydrobromide is contra-indicated, small doses of tetrachlorethylene in a gelatin capsule produce satisfactory results, but must also be used with caution.

Prophylaxis.—The tapeworms of the *Canidæ* and *Felidæ* are of great importance on account of the diseases caused by their intermediate stages, which occur in domestic animals and man, rather than on account of the effects of the adult parasites. Since the intermediate stages cannot be killed by means of drugs* and the diseases caused by them are difficult or impossible to treat, the regular treatment of dogs and cats for tapeworms, and the extermination of wild animals which harbour the same worms, are the only rational measures to be adopted. In the case of *Dipylidium* the kennel and its surroundings should also be cleaned and disinfected to prevent fleas from breeding there.

Related to *Dipylidium* are the genera *Joyeuxiella* and *Diplopylidium.* Species of both these genera occur in cats. In *Joyeuxiella* the rostellum bears a large number of rows of hooks resembling those of *Dipylidium,* while *Diplopylidium* has a few rows of hooks with the guard and handle well developed. In both genera the egg-capsules contain only one egg each. They develop apparently through dung beetles, and use lizards and other reptiles as secondary intermediate hosts.

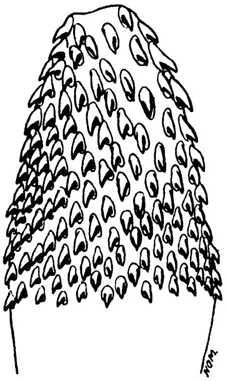

FIG. 65. — *Joyeuxiella fuhrmanni*, ROSTELLUM. (ORIGINAL.)

Genus **Metroliasthes** Ransom, 1900

M. lucida Ransom, 1900, is a rather rare parasite occurring in the small intestine of the fowl and turkey in North America, India and Africa. It is about 20 mm. long and 1·5 mm. wide. The scolex is devoid of a rostellum and hooks. The genital pores are single, irregularly alternating and often prominent. There are 30-40 testes in each proglottis. In the gravid segments the eggs pass into a large par-uterine organ. The intermediate hosts are grasshoppers, according to Jones.†

Family HYMENOLEPIDIDÆ

These cestodes are usually provided with a rostellum which bears a single row of hooks, but the suckers are usually unarmed. The genital pores are unilateral, rarely double. The genital organs are as a rule single and the testes are few in number, mostly 3 per segment. The uterus is generally persistent and sac-like. The eggs are enclosed in three envelopes,

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* A case may be mentioned here of a sheep which had received experimentally 228 c.c. of carbon tetrachloride in doses varying from 5 to 20 c.c. during a period of 30 days, and at autopsy had two live specimens of *Cysticercus tenuicollis* attached to the liver.

† *Proc. Helm. Soc. Wash.*, 3 (1): 26. 1936.

Genus **Hymenolepis** Weinland, 1858

This genus contains a large number of species which occur chiefly in domestic and wild birds. They are rather difficult to distinguish, but a generic diagnosis is sufficient for most practical purposes. The worms are usually narrow and thread-like in appearance, and there are always 3 testes in each mature segment. The ovary shows as a fourth globular body, and the cirrus-sac and receptaculum seminis may also be large.

H. lanceolata is a large form, measuring up to 130 mm. long and 18 mm. in width. The proglottides are much broader than long. It occurs in ducks and geese, and is one of the most harmful parasites of this group.

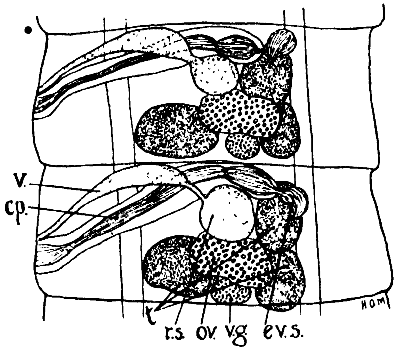

FIG. 66.—*Hymenolepis carioca*, MATURE PROGLOTTIDES. (ORIGINAL.)
c.p., Cirrus pouch; *e.v.s.*, external vesiculum seminalis; *ov.*, ovary; *r.s.*, receptaculum seminis; *t.*, testes; *v.*, vagina; *v.g.*, vitelline gland.

Life-Cycle.—The intermediate hosts, as far as they are known, are arthropods. The species which occur in aquatic birds are transmitted by fresh-water crustacea, usually copepoda. One of the commonest species found in the fowl is *H. carioca*, which has an unarmed scolex and is transmitted, according to American workers, by the beetles *Aphodius granarius*, *Chœridium histeroides*, *Hister*-14-*striatus* and probably *Anisotarsus agilis*.

Pathogenicity, etc.—In heavy infections these parasites may cause marked symptoms (see p. 108).

Genus **Fimbriaria** Fröhlich, 1802

F. fasciolaris (Pallas, 1781) occurs in the small intestine of the fowl, duck, goose and many wild birds. It varies in length from 25-425 mm. The scolex is small and provided with 10 hooks, but it is usually lost and the anterior portion of the body forms a folded expansion or "pseudo-scolex," by means of which the parasite attaches itself. Externally the body is finely segmented, but this does not correspond to the internal arrangement of the organs. The genital pores are unilateral, and there are 3 testes to each set of genital organs. The uterus is continuous throughout the strobila and posteriorly breaks up into tubules, which each contain several eggs. The latter measure 35-45 μ in diameter.

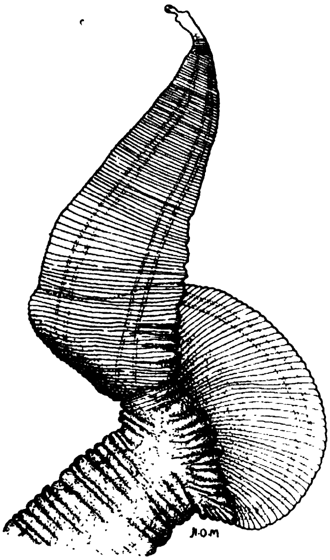

FIG. 67. — *Fimbriaria fasciolaris*, SCOLEX AND PSEUDOSCOLEX. (ORIGINAL.)

Life-Cycle.—The cysticercoid has been found in the water flea, *Diaptomus vulgaris.*

Family TÆNIIDÆ

The *Tæniidæ* are usually large tapeworms. The gravid segments are longer than wide. The rostellum is usually armed with a double row of large and small hooks which have a characteristic shape. The genital pores are single and irregularly alternating. There are, as a rule, a large number of testes, and the ovary is situated in the posterior part of the proglottis. The uterus has a median longitudinal stem and lateral branches. The embryonic egg-shell is thick and radially striated. The intermediate stage is a cysticercus, a multiceps or an echinococcus.

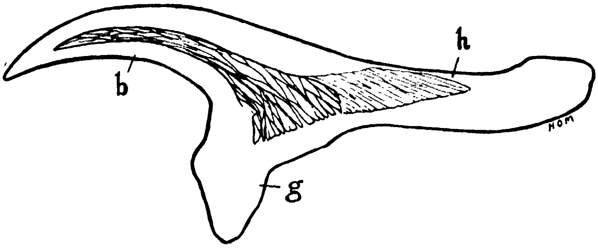

FIG. 68.—ROSTELLAR HOOK OF A *Tænia*. (ORIGINAL.)
b., Blade; *g.*, guard; *h.*, handle.

Genus **Tænia** Linnæus, 1758

T. solium Linnæus, 1758, occurs in the small intestine of man. The parasite is of great veterinary importance because the intermediate stage is found in the pig and dog. The worm is usually 3-5 m. long, rarely up to 8 m. The scolex is 0·6-1 mm. wide, and the rostellum bears 22-32 hooks in two rows, one row of large hooks measuring 0·14-0·18 mm., and one of small hooks measuring 0·11-0·14 mm. The gravid segments are 10-12 mm. long by 5-6 mm. wide. The uterus has 7-12 side-branches on either side. The embryonic egg-shell is roughly spherical, measuring 0·042 mm. in diameter. The gravid segments, which each contain about 40,000 eggs, are frequently detached in short chains and are passed in the fæces of the host. The worm may live in man for many years, and more than one may be present in an individual.

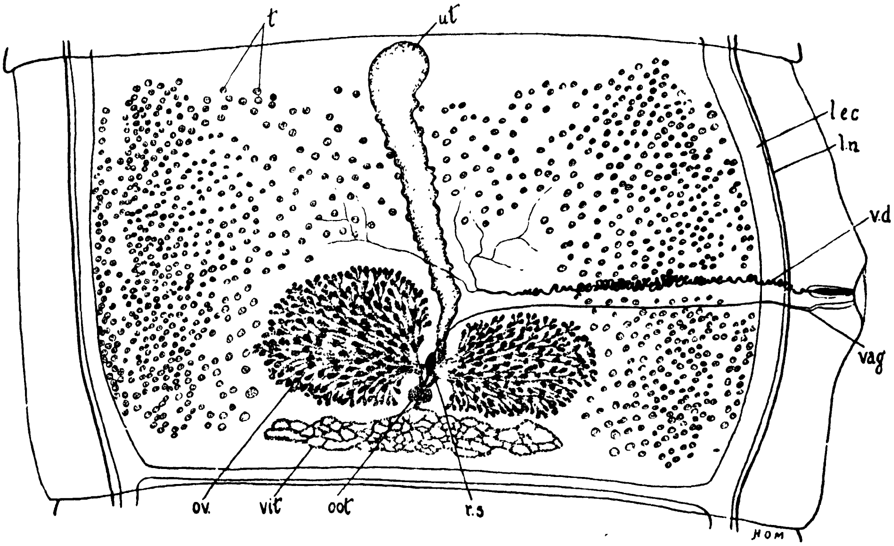

FIG. 69.—*Tænia solium*, MATURE PROGLOTTIS. (ORIGINAL.)

l.e.c., Longitudinal excretory canal; *l.n.*, lateral nerve; *oot.*, oötype and Mehlis' gland; *ov.*, ovary; *r.s.*, receptaculum seminis; *t.*, testes; *ut.*, uterus; *vag.*, vagina; *vit.*, vitellarium; *v.d.*, vas deferens.

Life-Cycle.—When the eggs are ingested by a pig the hexacanth embryo hatches in the intestine and penetrates into the wall of the gut, reaching the bloodstream, by which it is carried to various parts of the body. Those embryos that become lodged in the muscles, and sometimes also other organs like the brain, develop into the intermediate stage, the " pork measle," *Cysticercus cellulosæ*. Man becomes infected by eating pork which contains viable cysticerci.

Besides the pig, a number of other animals have been mentioned as intermediate hosts, including sheep, goat, cattle, various other ruminants, horse, dog, bear and monkeys, but the identification of the cysticerci was undoubtedly erroneous in many cases; only the pig and the dog can definitely be regarded as the intermediate hosts of this parasite. The cysticercus can, however, also develop in man, and is then found frequently in the brain or eyeball, causing serious disturbances. The parasite is therefore a serious menace to the life of its host.

The cysticercus requires about 10 weeks for its complete development in the pig. After about 2 months the bladderworm is already infective, as the suckers and hooks are sufficiently well developed to allow the scolex to attach itself. The fully developed bladder measures up to 20 by 10 mm., and contains an invaginated scolex which resembles that of the adult worm. It is situated in the intermuscular connective tissue and is surrounded by a relatively thin connective tissue capsule formed by the host. The visibility of this capsule allows the detection of the parasite at an early age, from about a fortnight after infection, when it shows as a small white nodule. The scolex, however, develops at a later stage, and the diagnosis of " measles " is usually made in meat inspection from the sixth week after infection.

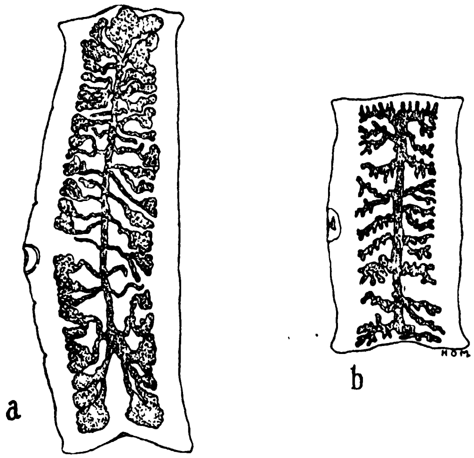

Fig. 70.—Gravid Segments of *a*, *Tænia saginata*; *b*, *Tænia solium*, × 1½. (After Mönnig.)

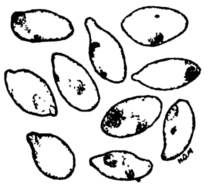

Fig. 71.—*Cysticercus cellulosæ*, as seen in Transmttied Light; Natural Size. (Original.)

The cysticerci are found chiefly in the muscles of the heart, tongue, forearm, thigh and neck, but may also occur in many other parts of the body. They may live in the pig for several years, but later they die and become calcified.

Symptoms.—Infected pigs show no symptoms as a rule, although in severe cases the flesh may be watery. Dogs with cysts in the brain may show symptmos resembling those of rabies.

Diagnosis.—The cysticerci can sometimes be felt under the tongue of the animal, but a negative finding is not conclusive. Serological diagnosis has been attempted, but is not specific, and would not be a practical measure under ordinary circumstances. A definite diagnosis can be made only by a thorough examination after the animal has been slaughtered.

Treatment and Prophylaxis.—No drug is known which will kill the cysticerci in the pig. An infected pig must be considered to be infected for the rest of its life, and can be used for breeding purposes, but not for human consumption, unless the pork is specially treated or well cooked.

Since man acquires his infection only by consuming raw, undercooked or insufficiently cured pork or ham, and the pig is infected through the eggs passed in the fæces of infected persons, prophylaxis is a matter of education, hygiene and proper meat inspection. The parasite is consequently rare in those countries in which such measures are practised and frequent in others where the population is ignorant of the facts, facilities for meat inspection are insufficient and pigs run about freely.

Cysticercus cellulosæ may remain viable in carcasses kept at about 0° C. for at least 6 weeks after the animal has been slaughtered, but is killed by lower temperatures as soon as the liquid in the bladder becomes frozen. In most countries infected pigs are condemned at meat inspection, and the losses incurred are in some cases considerable where the infection reaches 10 per cent. or more, although the tapeworms in human beings may be comparatively rare. This is due to the fact that the pig is a scavenger, and is consequently very liable to acquire the infection. In most countries this worm is therefore of greater importance as an economic problem of the pig-breeder than as a human parasite.

Pigs should not run on free range where human excreta may be found, and all persons concerned in pig-raising should be regularly examined and treated for tapeworms if necessary.

T. saginata Goeze, 1782, occurs in the small intestine of man, while the intermediate stage is found in cattle. This worm is usually 4-8, rarely up to 10 m. long. The scolex is 1·5-2 mm. wide, and has neither rostellum nor hooks. The gravid segments are 16-20 mm. long and 4-7 mm. wide, and contain each about 100,000 eggs. They are usually shed singly and may leave the host spontaneously. The gravid uterus has 15-35 lateral branches on either side. The embryonic egg-shell is roughly spherical, and measures about 45 μ in diameter.

Life-Cycle.—Similar to that of *T. solium*, but cattle act as intermediate hosts. Several other ruminants, including sheep, goat, llama, etc., have been recorded as carriers of the bladderworm, *Cysticercus bovis*, but the correctness of at least some of the identifications is doubtful. The cysticercus has also been found in man, but more rarely than *C. cellulosæ*. It requires about 18 weeks for its complete development in the bovine, but would be infective already somewhat earlier. The full-grown bladderworm measures 7·5-9 by 5·5 mm. and is usually situated in the intermuscular connective tissue, surrounded by a connective tissue capsule. The diagnosis of "beef measles" is usually made in meat inspection from about 6 weeks after infection. Cases of infection in calves suspected to have occurred before birth have been reported.

The cysticerci are found chiefly in the muscles of the jaws, heart, diaphragm and shoulder, but also in many other parts of the body, not always in muscle, but also in fat. In some cases the wall of the œsophagus seems to be a favourite seat, and this may be the only organ infected. About a year after development has been completed the cysticerci die and become calcified, and later disappear completely. A fairly strong immunity develops against re-infection.

Symptoms are not shown by infected cattle.

Diagnosis is made after the animal has been slaughtered by finding the cysticerci with unarmed heads. Ante-mortem diagnosis is not possible except by serological methods, which are, however, not sufficiently specific to be of much value.

Treatment and Prophylaxis.—As in the case of *C. cellulosæ*. The adult tapeworm is more common all over the world than *T. solium* on account of the fact that the diagnosis of measles in cattle is more difficult than in the case of pigs, and because lightly infected carcasses are passed for human consumption after special treatment, which appears not to have been quite effective in the past. It was formerly accepted in most countries that *C. bovis* is no longer infective 21 days after slaughter of the host, and lightly infected carcasses were passed for consumption after they had been kept in cold storage for this period. Recent investigations, however, proved conclusively that this period is too short and the shortest effective period is now not known. On the other hand, it has been shown by various investigators that the cysticercus is killed by low temperatures as soon as the liquid in the bladder becomes frozen, and that this requires up to 10 days for cysticerci in fat beef quarters, when they are kept at −8° to −10° C. Such treatment is now applied to lightly infected carcasses.

Adult cattle do not become infected as readily as pigs, since they graze high and are not scavengers. The infection in most countries is not over 1 per cent. Calves, however, have the habit of licking at various objects and are frequently infected at an early age. The problem is of great economical importance from the beef-breeder's point of view and causes many difficulties where butchers buy cattle for slaughtering purposes.

T. hydatigena Pallas, 1766 (syn. *T. marginata*) occurs in the small intestine of the dog, pine marten, stoat, weasel, polecat, related wild carnivora like the jackal, and perhaps in the cat. This is a large worm, measuring 75-500 cm. long. The rostellum bears 26-44 hooks in two rows, the large hooks being 0·17-0·22 mm. long and the small ones 0·11-0·16 mm. The gravid segments measure 10-14 by 4-7 mm., and the uterus has 5-10 branches on either side.

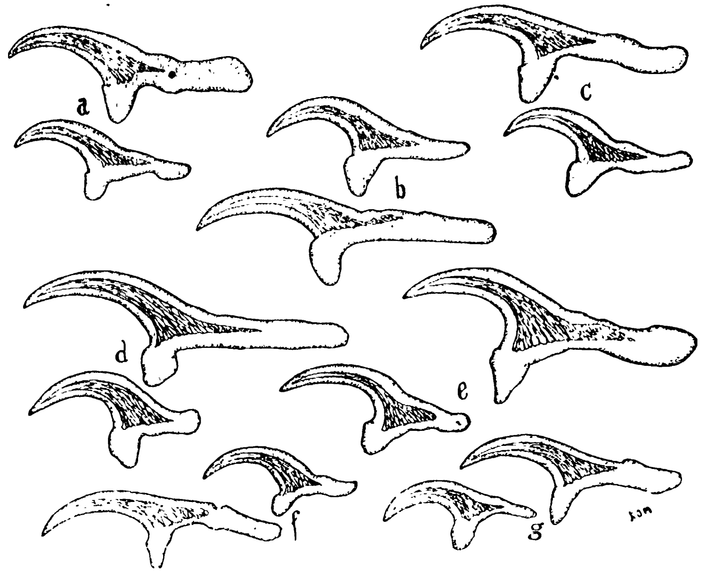

Fig. 72.—Rostellar Hooks of *Tænia* Species. (Original.)
a, *T. solium*; *b*, *T. hydatigena*; *c*, *T. ovis*; *d*, *T. pisiformis*; *e*, *T. tæniæformis*; *f*, *T. multiceps*; *g*, *T. serialis*. (All × 100, except *e* × 50.)

It must be pointed out that the identification of the *Tænia* species of carnivora is not an easy matter and should be left to a specialist.* As far as the veterinarian is concerned, all tapeworms of dogs are treated alike, and the intermediate stages which are important are easily recognised.

Life-Cycle.—The intermediate stage is known as *Cysticercus tenuicollis* and occurs normally in the peritoneal cavity of sheep, goat, cattle, pig, squirrel, hamster and wild ruminants. It has also been recorded from the dog, cat, rodents, monkeys and man, but the correctness of this is uncertain. The hexacanth embryos, after hatching in the intestine, reach the liver via the blood and break out of the portal vessels. Occasionally they may pass into the posterior vena cava and be transported to other parts of the body, but usually they burrow small channels in the liver parenchyma, eventually reaching the surface of that organ, and enter the peritoneal cavity after about 3-4 weeks. The stages in the liver may measure up to 8·5 by 5 mm. and resemble unripe cucumber seeds. There is an invagination at one end, but the scolex is not yet developed. The adult bladderworm may be found anywhere in the abdominal cavity, lying in a delicate cyst formed by the peritoneum. The vesicle may be 5 cm. or more in diameter and contains a watery fluid and a scolex invaginated into a long neck. The final host becomes infected by ingesting the cysticercus.

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* See Hall, "The Adult Tænioid Cestodes of Dogs and Cats and of Related Carnivores in North America," *Proc. U.S. Nat. Mus.*, 55: 1-94. 1918.

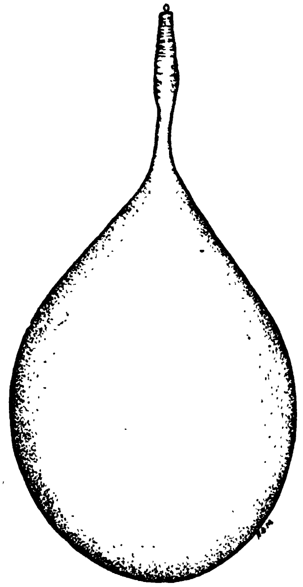

FIG. 73.—*Cysticercus tenuicollis* WITH HEAD EVERTED; NATURAL SIZE. (ORIGINAL.)

Pathogenicity and Symptoms.—With respect to the adult parasite, see p. 101. The disease produced by the intermediate stages is known as *hepatitis cysticercosa.* The cysticerci break down the liver parenchyma during their migration, causing hæmorrhages and leaving behind them a track of detritus. A few larvæ cause no appreciable damage nor symptoms, but in heavy infections the liver lesions may be so extensive or the hæmorrhages so severe that the animal dies. Peritonitis is frequently present. The condition is usually seen only in young animals. The course of the disease may be peracute, when hardly any symptoms are seen. In less rapidly fatal cases the animal is markedly depressed, weak, and the appetite is lost. If peritonitis develops, the temperature is elevated and ascites may be present. The adult cysticercus usually causes no harm to the host.

Post-Mortem.—The main lesions are seen in the liver, which shows on section, and frequently also on the uneven surface, a number of dark-red foci and streaks which have a diameter of about 2 mm. The organ may be fragile in consistence and the young worms are found in the burrows. Lesions associated with peritonitis may be present. Foci of broncho-pneumonia and pleuritis have been described, being due to young cysticerci which entered the lungs.

Treatment and Prophylaxis.—In the case of a light infection without symptoms no treatment is necessary. Hepatitis cysticercosa cannot be treated except by nursing the animal. The condition should be prevented by regular treatment of dogs for tapeworms and by destroying cysticerci found in slaughtered animals.

T. pisiformis (Bloch, 1780) (syn. *T. serrata*) occurs in the small intestine of the dog, fox, several wild carnivora and rarely the cat. It may grow up to 200 cm. long. The rostellum bears 34-48 hooks in two rows, the large hooks being 0·225-0·294 mm. long and the small ones 0·132-0·177 mm. The gravid segments measure 8-10 by 4-5 mm., and the uterus has 8-14 lateral branches on either side.

Life-Cycle.—Similar to that of *T. hydatigena*, but the intermediate hosts in this case are rodents, chiefly rabbits and hares. The young stages, after having developed in the liver for about 15-30 days, penetrate through the parenchyma of this organ and the adult bladderworm is found in the peritoneal cavity attached to the viscera. It is a small cyst, about the size of a pea, as implied by its name, *Cysticercus pisiformis.*

Pathogenicity and Symptoms.—With reference to the adult parasite, see p. 110. In the intermediate host a hepatitis can be produced by heavy infections, as in the case of *C. tenuicollis.* The affected animal may die suddenly, or in more chronic cases it is inactive and emaciation develops as the result of digestive disturbances.

Treatment and Prophylaxis.—As in the case of *C. tenuicollis.* Where rabbits are bred dogs should not have access. Foxes should not be fed with rabbits which are not definitely known to be free of cysticerci.

T. ovis (Cobbold, 1869) occurs in the small intestine of the dog and fox in many parts of the world. It grows to about 1 m. in length. The rostellum bears 24-36 hooks, of which the large ones are 0·156-0·188 mm. long and the small ones 0·096-0·128 mm. The uterus in the gravid proglottides has 20-25 lateral branches on either side.

Life-Cycle.—Similar to that of *C. cellulosæ.* The cysticercus, *C. ovis*, is found in sheep and goats, mainly under the epicard and the pleura of the diaphragm, but also in other muscles and organs. It grows mature in about 3 months and has about the same size as *C. cellulosæ.* The tapeworm grows adult in the dog in 7 weeks.

Pathogenicity, etc.—The parasite is not very frequent and its main significance is that the cysticercus may be mistaken for *C. cellulosæ.* This probably accounts for some of the records of the pork measle in sheep. For preventive measures, see p. 112.

T. tæniæformis (Batsch, 1786) (syn. *T. crassicollis*) occurs in the small intestine of the cat and other related carnivores, including the stoat, the fox and the lynx (*Lynx unita*), and is of cosmopolitan distribution. It is 15-60 cm. long and has a characteristic appearance on account of the absence of a neck and the bell-shaped posterior proglottides. The scolex is 1·7 mm. wide and bears a large rostellum with 26-52, usually 34, hooks. The large hooks are 0·38-0·42 mm. long and the small ones 0·25-0·27 mm. The suckers are prominent, facing outwards and forwards.

Life-Cycle.—The bladderworm stage, *Cysticercus fasciolaris*, develops in the livers of the intermediate hosts, which are rodents, chiefly rats and mice, and also the rabbit, the squirrel and the muskrat. The vesicle is small and the scolex is not invaginated, but is connected to the vesicle by a long "neck," which is segmented. When the cysticercus is ingested by the final host the vesicle and the neck are digested off, and the scolex grows a body, as usual.

Pathogenicity, etc.—The tapeworm penetrates with its head deeply into the mucosa, even causing perforation in rare cases. It has been described as causing severe symptoms of digestive disturbance, nervous disorders and loss of sight. The cysticercus appears to be fairly harmless, at least in rats, even when it occurs in large numbers, but it may incite the development of malignant growths in the liver and has been widely studied on account of this fact. For treatment of cats, see p. 111.

T. krabbei Moniez, 1789, is a tapeworm of the dog occurring in northern countries. The intermediate stage, *Cysticercus tarandi*, is found in the muscles of reindeer. The worm is about 26 cm. long or longer. There are 26-34 hooks, the large ones being 0·148-0·17 mm. long and the small ones 0·085-0·12 mm. The mature segments are much broader than long, and the organs are compressed and transversely elongated. The uterus has 9-10 lateral branches on either side.

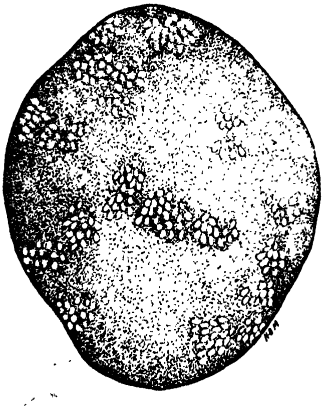

FIG. 74.—*Multiceps multiceps*; NATURAL SIZE. (ORIGINAL.)

T. multiceps, Leske, 1780, occurs in the small intestine of the dog, coyote, fox and jackal, and is found in most parts of the world. It is 40-100 cm. long and has a small head, 0·8 mm. in diameter. There are 22-32 hooks; the large ones are 0·15-0·17 mm. long and the small ones 0·09-0·13 mm. The gravid segments measure 8-12 by 3-4 mm., and the uterus has 9-26 lateral branches on either side.

Life-Cycle.—The intermediate stage, *Multiceps multiceps* (syn. *Cœnurus cerebralis*), develops in the brain and spinal cord of the sheep, goat, cattle, horse and other ungulates and has also been found in man. The embryos, after hatching in the intestine, pass via the bloodstream to various parts of the body.

PLATE IX

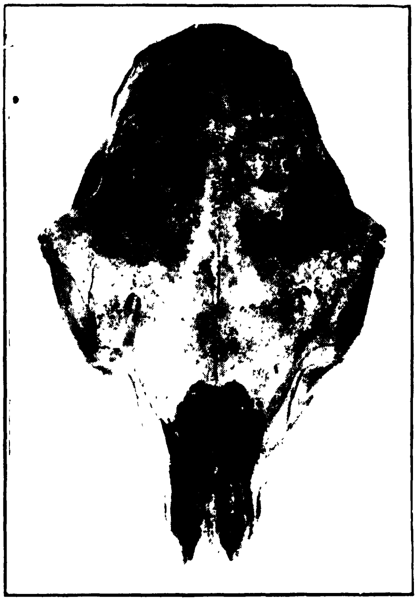

FIG. 75.—SKULL OF SHEEP SHOWING PERFORATION CAUSED BY *Multiceps multiceps.* (ORIGINAL.)

[*To face page* 122.

Only those that reach the central nervous system will develop; the others soon die off. The young cysts wander about in the brain before settling down and are fully developed in 7-8 months. The full-grown cyst measures 5 cm. or more in diameter. It has a delicate, translucent wall, and bears on its inner surface a number of heads which may amount to several hundred, and each resembles the scolex of the adult worm. The final host acquires the infection by ingesting the bladder-worm, and all or most of the fully-formed heads develop into tapeworms.

Pathogenesis and Symptoms.—With reference to the adult parasite, see p. 110. The intermediate stage or multiceps (*cœnurus*) causes the disease known as "gid" or "sturdy" or *cœnurosis cerebralis*. From about 1-3 weeks after infection, when the young worms wander about in the brain, the sheep may show an elevated temperature and other symptoms associated with a cortical encephalitis or meningitis, which is caused by the parasite. This will, however, happen only when several parasites invade the brain simultaneously, and in many cases these preliminary symptoms do not appear. Quite exceptionally an animal may die at this stage owing to a very severe infection. As a rule these symptoms abate and the animal appears healthy for several months, until the cysts begin to exert pressure. The scolices may also be evaginated and come into contact with the brain, causing irritation.

The characteristic symptoms of the disease are therefore seen from about 2-7 months after infection. The animal performs forced movements, varying in nature with the position of the parasite in the central nervous system. Most frequently the cyst is situated in the parietal region on the surface of one of the cerebral hemispheres. The animal then holds its head to one side and turns in a circle towards the affected side. Many such sheep are blind in the eye on the opposite side. If the parasite is lodged in the anterior part of the brain, the head is held against the chest and the animal steps high ("trotters"), or it may walk in a straight line until it meets an obstacle and then remain motionless for a time. The cyst may also occur in a ventricle, in which case the movements are to some extent the reverse of those described. If the cyst presses on the cerebellum, the animal is in a hyperæsthetic condition, easily frightened, and it has a jerky or staggering gait in the hind legs which gradually grows worse and finally leads to prostration. The sight of the animal and the expression of its eyes are frequently affected, and grinding of the teeth, salivation, complete loss of balance and convulsions may be seen. All these symptoms occur intermittently, and appear especially when the animal starts grazing after a rest. Sometimes the cyst is localised in the lumbar region of the spinal cord, causing progressive paresis of one or both hind limbs and of the pelvic organs.

The animal soon becomes indifferent to food and water, wanders from the flock, and eventually dies of emaciation or through direct affection of a vital nerve centre.

If the parasite is situated on the surface of the brain, the skull undergoes pressure atrophy, even to the extent of perforation, so that on examination the affected part can be localised, as it yields to pressure. Such manipulation causes pain and may incite a spell of symptoms.

Diagnosis.—The symptoms must be differentiated from those caused by blindness and other conditions affecting the brain, like a depressed fracture of the skull, vertigo, meningitis, tumours, abscesses, poisoning by certain plants (*e.g. Matricaria nigellæfolia*, which causes "pushing disease" in cattle), louping ill and heartwater, for which the history of the case, locality, etc., are of great importance. It is frequently, however, not possible to arrive at a definite diagnosis except by conducting a post-mortem examination.

Post-Mortem.—Animals which die in the early stages show an inflammation of the meninges and a number of sinuous tracks on the surface of the brain, at the ends of which the young bladderworms can be found. Such tracks may then also be present in other organs—for instance, the heart and lungs.

Animals which die in the later stages of the disease are emaciated and may be anæmic. The multiceps, or more than one, is found on or in the brain, often lying in a cavity produced by pressure and surrounded by necrotic material. Or it may be found in the vertebral canal, especially in the lumbar, cervical or medullary regions. There may be local pressure atrophy or perforation of the skull. In old cases the cyst has sometimes degenerated and can be identified only by finding the hooks.

Treatment.—If the cyst is situated on the surface of the brain and can be located, especially by palpation, it can be removed after trephining or by means of a special trocar and canula.* In other cases treatment is useless and the animal should be slaughtered before it becomes too emaciated.

Prophylaxis.—The bladderworms found in affected animals should be destroyed, to prevent the final hosts from eating them. It is advisable to kill giddy sheep, as they would be easy prey for wild carnivora and serve to spread the infection. Dogs should be treated regularly for tapeworms and wild carnivora, which may act as intermediate hosts, should be destroyed. It is probable that in some countries the infection is kept going between antelopes and carnivores, since occasionally epizootics of gid are seen in sheep even where no dogs are present.

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* See Gillard, *Vet. Journ.*, 88 (5): 214-218. 1932.

T. gaigeri Hall, 1916, occurs in the small intestine of the dog in various parts of the world. It measures up to 182 cm. in length, and the rostellum bears 28-32 hooks. The large ones are 0·16-0·18 mm. long and the small ones 0·115-0·15 mm. The gravid uterus has 12-15 lateral branches on either side.

Life-Cycle.—The intermediate stage, *Multiceps gaigeri*, is of about the same size and appearance as that of *T. multiceps*, and it develops in the intermuscular connective tissue, central nervous system and other organs of the goat.

Pathogenicity.—The parasite is not very common and has little significance. When it occurs in the central nervous system it may cause gid.

T. serialis Gervais, 1847, is a tapeworm of the dog and fox and has a cosmopolitan distribution. It grows to a length of 72 cm., and the scolex bears two rows of 26-32 hooks. The large hooks are 0·135-0·175 mm. long and the small ones 0·078-0·12 mm. The gravid uterus has 20-25 lateral branches on either side.

Life-Cycle.—The intermediate stage, *Multiceps serialis*, develops in the intermuscular connective tissue of the hare, rabbit, coypu and squirrel and has also been found in man.* The full-grown cyst is usually ovoid in shape and about 4 cm. long, but may be larger. It develops a number of scolices, which are invaginated into their necks. Internal as well as external daughter bladders may be formed, and these are also able to produce scolices. The dog acquires the infection by eating the raw flesh of infected rodents.

Significance.—The multiceps is not very pathogenic; severe infections in fur-bearing animals may be important. Infected rabbits or hares are not fit for sale for human consumption. With regard to the adult parasite, see p. 110.

Treatment and Prophylaxis.—Dogs and foxes can be treated for the tapeworm, and dogs should not have access where fur-bearing rodents are bred. Infected rodents must not be fed to the final hosts.

Genus **Echinococcus** Rudolphi, 1801

E. granulosus (Batsch, 1786) is a tapeworm which is found in the small intestine of the dog, cat,† fox and several wild carnivora. It is only 2·5-9 mm. long, and usually has not more than four proglottides, of which the posterior one is gravid and frequently as large as the rest of the body. The scolex is armed with two rows of hooks, about 30-36 in number, the large ones being 0·040-0·049 mm. long and the small

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* *Bull. Soc. Path. Exot.*, 26 (8): 1060-1071. 1933.

† In the cat the parasites die before reaching sexual maturity.

ones 0·030-0·042 mm. The genital pores alternate irregularly. There are 30-53 testes in each segment. The eggs are typical *Tænia* eggs; the embryonic egg-shell is slightly ovoid and measures 32-36 by 25-30 μ.

Life-Cycle.—After the eggs have been ingested by the intermediate host they hatch in the intestine and the embryos migrate to the bloodstream, which carries them to various organs. The intermediate hosts include man and all domestic mammals, also the dog and cat, as well as numerous wild mammals. The embryo grows into a large vesicle, 5-10 cm. or more in diameter, known as an echinococcus or "hydatid," which has a fairly thick cuticle, concentrically laminated, and an internal germinal layer. The latter produces numerous small vesicles or brood capsules about 5-6 months after infection, and scolices are formed in these and perhaps also on the germinal layer directly. Each brood capsule may contain up to 40 scolices invaginated into their neck portions and attached to the wall by stalks. The scolices and their stalks are covered by a cuticular layer. The brood capsules may become detached from the wall of the vesicle and float freely in the vesicular fluid, giving rise to the term "hydatid sand." They may rupture and turn inside out. The final host acquires the infection by ingesting fertile hydatids. The worm grows adult in the dog in 6-7 weeks.

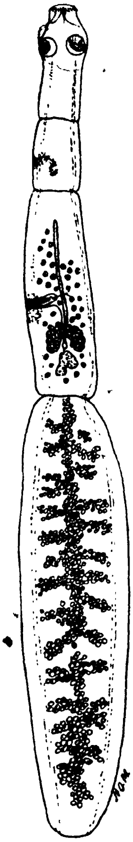

FIG. 76. — *Echinococcus granulosus*, ENTIRE SPECIMEN. (ORIGINAL.)

All echinococcus bladders do not form scolices; a large percentage are frequently sterile. In cattle 90 per cent. are sterile, in pigs about 20 per cent., and in sheep 8 per cent. The sheep is therefore apparently the most normal intermediate host among the domestic animals.

The echinococcus is filled with a clear, colourless or pale yellow fluid, having a specific gravity of about 1·017. It contains little protein and fat, about 3 per cent. salts and a small quantity of succinic acid. Cysts in the liver may contain bile pigments and those occurring in the kidneys may contain traces of urine. The echinococcus has been found in practically all organs, but occurs chiefly in the lungs and liver in domestic animals.

The bladder is normally spherical in shape, but its appearance depends on the organ in which it grows, as it is moulded by the resistant tissues; for instance, in the liver by the bile ducts. An echinococcus growing in bone is a reticular structure which fills the Haversian and marrow canals. It causes erosion of the bone and may predispose to fracture. Such cysts usually do not form scolices except where they reach the surface and are able to grow normally.

Multiplication of the echinococcus can take place in various ways. Any factor which threatens the life of the cyst—for instance, entrance of bile—will lead to the formation of daughter cysts inside the original bladder. These are called endogenous daughter cysts and are formed from detached fragments of the germinal layer or from brood capsules or scolices, the latter being able to undergo regressive changes and develop into cysts. The daughter cyst is covered with cuticle and lined with a germinal layer and it can produce brood capsules, scolices and granddaughter cysts, like the original bladder. Exogenous daughter cysts are formed by budding outward. This usually happens when a piece of the germinal layer becomes enclosed in the cuticle on account of uneven growth. As the cuticle is shed on the outside and formed inside, the enclosed tissue will gradually move outwards and there give rise to a new bladder.

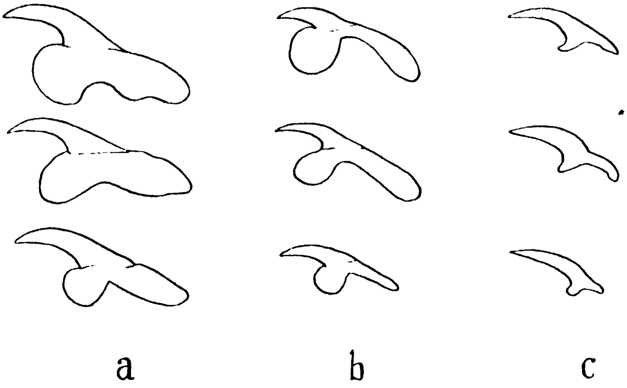

FIG. 77.—ROSTELLAR HOOKS OF *Echinococcus granulosus.* (ORIGINAL.)
a, Large hooks; *b*, small hooks; *c*, hooks from bladderworm.

The echinococcus may burst into a cavity—for instance, the peritoneum—and the liberated scolices, brood capsules and germinal layer can all form new bladders. For this reason it is dangerous to puncture the cyst and allow the fluid to escape into the body.

The so-called " echinococcus multilocularis " of cattle, which is frequently seen in the livers of these animals, is a conglomeration of small sterile bladders, each about 1 cm. in diameter, separated from one another by fibrous tissue. Somewhat similar to this, but differing from it in essential features, is the " echinococcus alveolaris " found in man in certain parts of Europe and Asia. This form consists of a fibrous stroma containing numerous small bladders, of which some may be fertile. The whole mass grows like a neoplasm infiltrating the liver tissue and entering the bloodvessels, thus giving rise to metastases in other organs. In the centre of the mass necrosis takes place and a large cavity is formed containing fluid.

Pathogenicity.—The tapeworm is comparatively harmless to the dog except when it occurs in large numbers, in which case a marked enteritis may be produced. See also p. 110.

The harmfulness of the echinococcus naturally depends on the organ in which it is situated and the severity of the infection. As the cysts gradually increase in size they may impair the health of the host and cause dyspnœa when they occur in the lungs, or digestive disturbances and possibly ascites when the liver is infected. In domestic animals disease due to echinococcus cysts is rare, but in the human being it is more dangerous on account of the frequent development of exogenous daughter cysts which escape into the peritoneal cavity from the liver, or leakage from primary cysts, both giving rise to multiple omental cysts. The significance of domestic animals as hosts of this parasite is therefore mainly that they act as reservoirs of the infection for man.

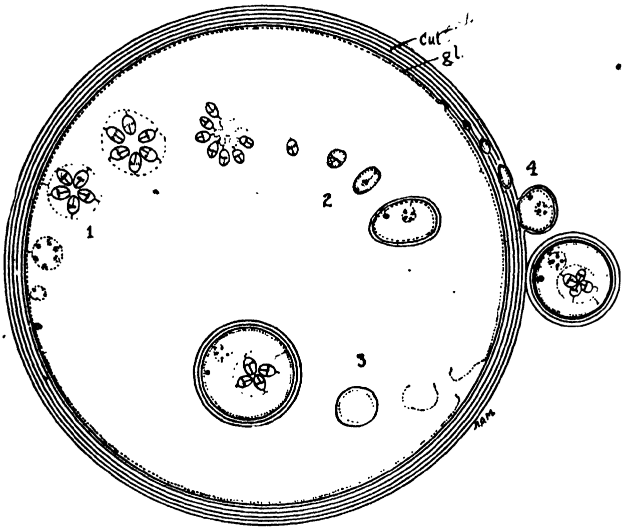

FIG. 78.—*Echinococcus granulosus*, DIAGRAMMATIC REPRESENTATION OF AN ECHINOCOCCUS. (ORIGINAL.)

cut., Cuticula; *g.l.*, germinal layer; 1, development of brood capsules and scolices; 2, transformation of scolex into endogenous daughter cyst; 3, formation of endogenous daughter cyst from germinal layer; 4, formation of exogenous daughter cyst.

Diagnosis of echinococcus infection in animals is rarely made in the living subject. When the liver is infected it may be enlarged and a fluctuating cyst may be determined by percussion. In the lungs percussion may also lead to the detection of a cyst. The Casoni reaction is rarely applied to animals.

Treatment and Prophylaxis.—No method of treatment, except by operation, is known for echinococcus infection. The disease can be prevented by regular treatment of dogs for tapeworms and the destruction of bladderworms found in slaughtered animals. It should be borne in mind that wild carnivora in zoological gardens and menageries

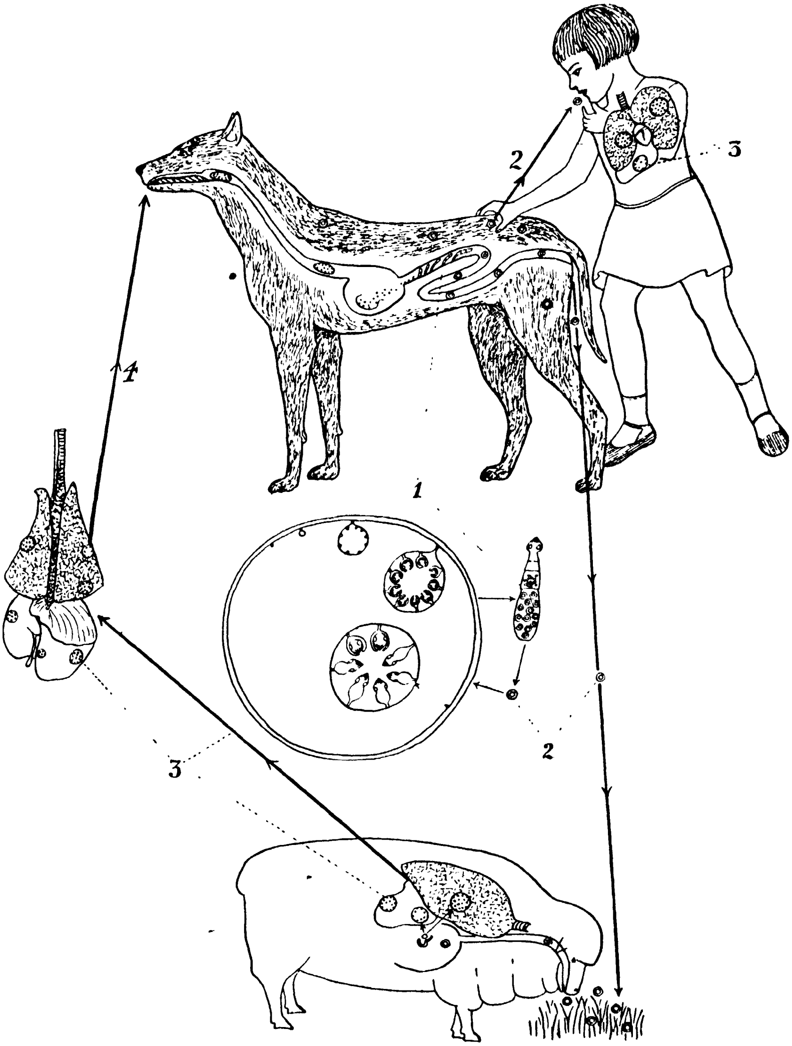

FIG. 79.—*Echinococcus granulosus*, LIFE-CYCLE. (ORIGINAL.)

may be a great danger when infected with *Echinococcus* tapeworms, and all meat fed to them should be carefully inspected. Dogs should get no raw offal to eat. Particular attention should be given to sheepdogs, and persons handling sheep must remember that the *Echinococcus* eggs tend to stick to the fleece, from where they may be transferred to human beings.

PHYLUM NEMATHELMINTHES

CLASS NEMATODA

The Nematoda are free-living or parasitic, unsegmented worms, usually cylindrical and elongate in shape. They are provided with a body cavity which is not lined with epithelium. An alimentary canal is present. With a few exceptions the sexes are separate and the life-cycle may be direct or include an intermediate host.

Morphology.—The shape of the body is elongate, cylindrical and tapering at the extremities. A few exceptions occur; for instance, the females of *Tetrameres*, which swell up after copulation, becoming almost spherical, and those of *Simondsia*, in which the posterior part of the body also assumes a globular shape.

The body is unsegmented, but the cuticula which forms the covering is usually provided with circular annulations, or it may be smooth or have longitudinal striations. The cuticula is relatively thick in nematodes and is continuous with the cuticular lining of the buccal cavity, the œsophagus, the rectum and the distal portions of the genital ducts. It may form special adhesive structures; for instance, hooks (*Rictularia*, *Tetrameres* males), simple or more complicated thickenings (*Gongylonema*, *Acuaria*) or a cephalic collar (*Physaloptera*). Many species have lateral cuticular alæ, especially in the cervical region (*Toxascaris*, *Physocephalus*, *Œsophagostomum*), and in most cases the males bear cuticular expansions at the posterior extremity.

The cuticula is formed by an underlying subcuticular layer. This usually consists of cells in the free-living forms and of a matrix containing a number of nuclei in the parasitic forms. This layer forms four longitudinal thickenings on the inner aspect, situated dorsally, ventrally and laterally and known as the "longitudinal lines." The lateral lines are the thickest and contain the longitudinal canals of the excretory system.

The muscular layer, which follows next and lines the body cavity, consists of a number of cells having a basal contractile portion which is transversely striated, and a cytoplasmic portion which contains the nucleus and is connected to the nerve trunk running in the dorsal or ventral line. The muscular layer is divided into four quadrants by the longitudinal lines. In each quadrant there may be two rows of muscle cells (meromyarian type, *e.g.* *Oxyuris*, *Strongylus*), or a large number of cells (polymyarian type, *e.g.* *Ascaris*).

The body cavity contains a fluid, which may be very harmful to the host if the worm is digested after having died in the intestine, and certain large cells, for instance, the so-called " phagocytic " cells of *Ascaris*.

The mouth is anterior, sometimes subdorsal or subventral, and is usually surrounded by lips. The original forms apparently had three lips, one dorsal and two ventral, each bearing two papillæ. This arrangement still persists in most free-living and some parasitic forms (*Ascaroidea*). In other forms there are two lips, each bearing three papillæ, and these lips may be subdivided into three parts each (*Spiruroidea*), or the lips may disappear completely (*Strongyloidea*, *Filaroidea*), and the papillæ stand around the mouth opening. The lateral papillæ are usually termed " amphids " and may differ in structure and function from the others. In the forms without lips secondary structures may develop in their place; for instance, the leaf-crowns of the *Strongylidæ*, a large number of fine, pointed processes which arise from the rim of the mouth opening (external leaf-crown) or the rim of the buccal capsule (internal leaf-crown). The mouth may lead into a buccal capsule, which has thick cuticular walls and may contain special tooth-like structures, or into a pharynx, which is usually cylindrical and surrounded by muscular tissue, or directly into the œsophagus. The latter is a strongly muscular organ with a triradiate lumen which is thickly lined with cuticula and divides the wall into three sectors, a dorsal and two subventral, corresponding to the primitive arrangement of the lips. One ray of the lumen, therefore, always points to the ventral aspect. The wall of the œsophagus contains three glands, one in each sector. The dorsal gland

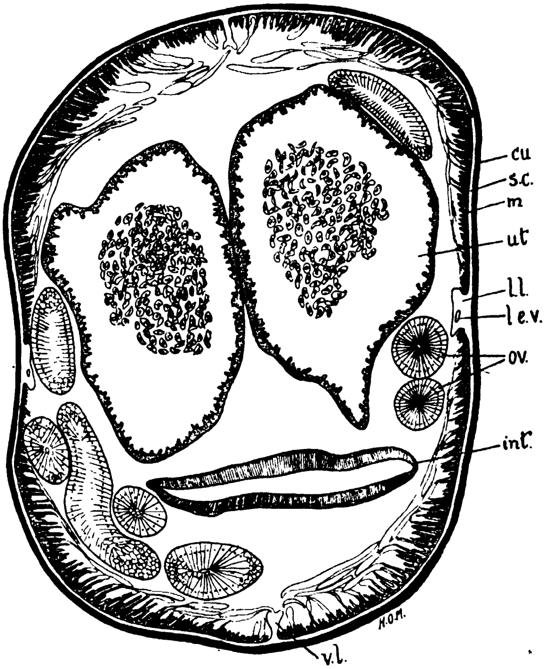

FIG. 80.—*Ascaris equorum*, TRANSVERSE SECTION OF FEMALE. (ORIGINAL.)

cu., Cuticula; *int.*, intestine; *l.e.v.*, longitudinal excretory vessel; *l.l.*, lateral line; *m.*, muscular layer, polymyarian type; *ov.*, ovary; *s.c.*, subcuticula; *ut.*, uterus; *v.l.*, ventral line.

opens into the mouth and the others into the lumen of the œsophagus. Their function is to secrete digestive enzymes. Posteriorly the œsophagus may have a bulbar swelling, containing a valvular apparatus. The function of the œsophagus is to suck in liquid food, which is passed into the intestine. In order to prevent regurgitation the œsophagus is separated from the intestine by three valves. The intestine is a simple tube with a non-muscular wall, composed of a single layer of columnar cells standing on a basal membrane. It leads into the rectum, which is lined with cuticula and into which the genital duct opens in the male; the latter, therefore, has a cloaca. The part of the body behind the anal or cloacal opening is called the tail. Several glands are usually present in the body; for instance, caudal glands opening near the end of the tail, rectal glands surrounding the rectum, and cephalic glands which lie free in the anterior part of the body cavity and open into or near the mouth. The latter are strongly developed in many blood-sucking nematodes (*Ancylostomidæ*) and apparently secrete a substance which prevents coagulation of the blood.

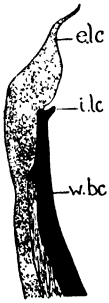

FIG. 81.—*Strongylus equinus*, SECTION THROUGH RIM OF BUCCAL CAPSULE. (ORIGINAL.)

e.l.c., External leaf-crown; *i.l.c.*, internal leaf-crown; *w.b.c.*, wall of buccal capsule.

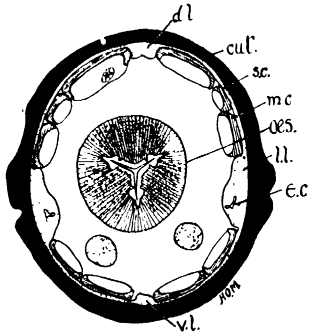

FIG. 82.—*Strongylus equinus*, SECTION THROUGH ŒSOPHAGEAL REGION. (ORIGINAL.)

cut., Cuticula; *d.l.*, dorsal line; *e.c.*, excretory canal; *l.l.*, lateral line; *m.c.*, muscle cell, meromyarian type; *œs.*, œsophagus; *s.c.*, subcuticula; *v.l.*, ventral line.

The excretory system opens by a ventral pore situated a short distance behind the anterior extremity and consists of a pair of lateral longitudinal vessels which do not end in flame-cells as in the flat-worms. Associated with this system is a pair of unicellular cervical glands which may be very large. The function of the excretory system and associated glands is not known and it may not be excretory.

The nervous system consists of a number of ganglia connected by fibres, forming the " nerve ring " which surrounds the œsophagus.

From this central organ six nerve trunks arise anteriorly and posteriorly, the principal ones running in the dorsal and ventral lines. Solitary ganglia occur in other parts of the body ; for instance, an anal ganglion. The only sense organs that occur in parasitic nematodes are tactile papillæ. These are found (1) around the mouth, as already described; (2) a pair situated laterally in the anterior region, the cervical papillæ; (3) frequently a lateral or subdorsal pair near the middle of the body; and (4) on the posterior extremity of the male, the genital papillæ, which are mostly paired and may have long stalks supporting the caudal alæ or the bursa of the strongyles. In the latter case the stalks contain muscle fibres and the papillæ are arranged according to a definite system. The female may also bear a pair of papillæ on the tail or in the region of the vulva.

The sexes are usually separate. In the parasitic nematodes the function of reproduction is markedly developed and there is much variation in the genital organs. Sexual dimorphism is sometimes very marked.

The male organs are composed of a single testis in the parasitic and most free-living forms, a vas deferens, sometimes a seminal vesicle and a muscular ejaculatory duct which opens into the cloaca. In most cases there are one or two spicules lying in sheaths which also open into the cloaca. These organs are cuticular, often pigmented, and they vary in shape and size and are of great value in determination of the species. They serve during copulation for attachment and probably also to expand the vagina and direct the flow of sperms. The spicules are moved by special muscles and in many cases the wall of the cloaca is provided with cuticular thickenings which guide the spicules. Such a thickening on the dorsal wall is called a gubernaculum. Less frequently there is one on the ventral wall, known as a telamon.

In the female the vulva was originally posterior and there were two uteri and two ovaries running forward (prodelph). Some free-living and also some parasitic forms have only one uterus and ovary. On the other hand, the uteri may be subdivided, so that forms with up to sixteen uteri are known. The vulva may be found in various positions, even quite close to the anterior extremity (*Oxyuridæ*, *Filaridæ*) and the uteri may run in opposite directions (amphidelph) or both run backwards (opisthodelph). The ovary is proximally a solid, cylindrical organ containing a number of cells, which divide to form the ova and further on arrange themselves around a central rhachis, from which they later become detached. They pass through an oviduct to the seminal receptacle, a small dilated part of the organ in which spermatozoa are stored and fertilisation takes place. This is followed by the uterus, in which the egg-shells are formed and the embryo may develop. The uteri are usually connected to the vagina by muscular ovejectors, or one for both uteri, lined with cuticula like the vagina. The vulva is usually situated on the ventral surface. Some nematodes are oviparous, others are ovoviviparous or viviparous. The eggs vary greatly in shape and size, a fact which is of great importance in making a specific diagnosis by fæces examination. The parasitic nematodes are very prolific and a female may lay several thousand eggs per day.

Development.—The original egg cell divides into two, then four and so on, and the embryo passes through a morula stage and later through a " tadpole " stage, in which the anterior end is broad and the embryo is bent double. Eventually the larva is fully formed and ready to hatch. Normally four moults or ecdyses, in which the whole cuticle is shed and replaced by a new one, take place before the adult stage is reached, but in some cases a moult may be skipped. Each period between two moults consists of two phases: one in which the worm feeds and grows, and the second during which it becomes inactive, or lethargic, while structural changes take place in the body in preparation for the next moult. The larval worm becomes infective for the final host as a rule after the second moult, and in those species which are free-living up to this stage the cuticle of the second moult is usually retained as a protective sheath until the worm has entered its host. Such sheathed larvæ do not feed and their habits differ much from those of the younger larvæ, as their only object is now to find a suitable host and to avoid conditions which may be fatal to them. The infective stage may, in certain species, be reached in the egg-shell, and in such cases one moult is apparently skipped (*Ascaris lumbricoides*, *Syngamus trachea*). The third and fourth ecdyses take place in the final host, after which the worms are in the adult stage and grow to maturity.

Various types of life-cycles are found among the nematodes, depending to some extent on the degree of adaptation to a parasitic existence that has been reached. The more complete this adaptation, the more unsuited is the parasite to lead a free existence, and the period which is spent outside the final host is shortened by remaining in the egg-shell or by adopting an intermediate host, or both. The most specialised forms have no period of free existence at all. The life-cycles may therefore be classified as follows:

I. Without an intermediate host.

- (i.) Eggs hatch and larvæ are free-living for a time, *e.g.* most *Strongylidæ* and *Trichostrongylidæ*.
- (ii.) Eggs do not hatch, but have to develop in the open, *e.g.* *Ascaridæ*.

II. With an intermediate host.

- (i.) Eggs hatch or the worms are viviparous and the larva enters the intermediate host after a short free existence, *e.g.* many *Metastrongylidæ*, *Habronema* spp.
- (ii.) Eggs do not hatch and are ingested by the intermediate host, *e.g.* most *Spiruroidea.*
- (iii.) The worms are viviparous and the larvæ enter the blood of the host, from which they are transferred to another host by blood-sucking intermediate hosts, *e.g.* most *Filaroidea.*

After having entered the final host many nematodes migrate through the body before settling down in their normal habitat, and some of them do much harm in a mechanical way during this process. It may appear to be a rather strange procedure in the case of intestinal parasites which have been swallowed by the host and which, after having arrived in the intestine, penetrate into the mucosa, in which they may pass some time before they return to the lumen. Or they may reach the blood and be transported to the liver and from there through the heart to the lungs, eventually migrating up the air-passages to the pharynx, to be swallowed down again. This migration is apparently not due to unsuitability of the intestine for the development of the young worms, according to the researches of Fülleborn, but it is a habit derived from more primitive ancestral forms which entered the host by penetrating through the skin. In their case the simplest way of reaching the intestine was to pass with the blood to the lungs and from there to the pharynx, to be swallowed down. Such parasites still exist—for instance, most *Ancylostomidæ*—and they provide an explanation for the migratory habits of other nematodes, which is not only interesting, but also exceedingly important in connection with the pathogenic effects of these parasites.

Classification.—Since there are free-living and parasitic nematodes, a satisfactory classification must take the whole group into account. The system adopted here is that given by Baylis and Daubney* with slight modifications. The parasitic nematodes are grouped in six orders, each of which contains one or more families.

Order ASCAROIDEA

This order contains those nematodes that have three lips, one dorsal and two subventral, each as a rule provided with two papillæ. The lips may in some cases be much reduced or apparently absent. The life-cycle is direct and, in the parasitic forms, the eggs usually do not hatch before they are swallowed by the host.

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* *A Synopsis of the Families and Genera of Nematodes*, British Museum (Natural History), 1926.

Family ASCARIDÆ

These are usually large worms with three well-developed lips and a simple, cylindrical œsophagus. The tail of the male is simple and bears a large number of small papillæ. The eggs are usually spherical in shape, and the shell is in most cases surrounded by a thick layer of albuminous material which has an uneven or pitted surface. The larvæ migrate through the lungs of the host before they grow adult in the intestine.

Genus **Ascaris** Linnæus, 1758

A. lumbricoides Linnæus, 1758 (syn. *A. suis*, etc.), is cosmopolitan in distribution and occurs in the small intestine of man, certain large apes and the pig. Immature specimens which have been described as *A. ovis* are occasionally found in sheep and cattle, and the parasite has also been recorded from certain squirrels and the dog. The worms found in man and the pig are morphologically and serologically indistinguishable, but are apparently " physiological " or " host " varieties. Many transmission tests from man to pig and vice versa have failed, but De Boer,* as well as Japanese workers, have infected pigs with human *Ascaris*.

The males measure 15-25 cm. by about 3 mm. and the females up to 41 cm. by 5 mm. The cuticle is relatively thick and the worms are fairly rigid. The dorsal lip bears two double papillæ and each ventrolateral lip one double subventral and a small lateral papilla. Each lip bears on its inner surface a row of minute denticles. The œsophagus is about 6·5 mm. long and simple in shape. The spicules of the male are about 2 mm. long and stout. There are a large number of precloacal papillæ, some of them standing in pairs on either side; of the postcloacal papillæ, two pairs are double and three single. The vulva opens near the end of the first third of the body. The vagina is short and leads into two posteriorly directed uteri. The eggs are oval, measuring 50-75 by 40-50 μ. They have thick shells and the albuminous layer bears prominent projections.

Life-Cycle.—It has been estimated that a female may lay as many as 200,000 eggs per day. The eggs are passed in the fæces of the host and develop to the infective stage in 10 days or longer, depending on the temperature. The eggs are very resistant to adverse conditions, like drying or freezing, and to chemicals, and they may remain viable for several years, but hot, dry conditions, as in sandy soil with direct sunlight, kill them in a few weeks. During its development the larva moults once in the egg-shell. The larvæ rarely hatch and infection usually takes place through ingestion of the eggs with food or water or from the soiled skin of the mother in the case of sucking pigs.

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* Diss., Utrecht, 1935.

The ingested eggs hatch in the intestine and the larvæ burrow into the wall of the gut. They may pass through into the peritoneal cavity and thence to the liver, but usually reach this organ via the bloodstream. From here they are carried by the blood through the heart to the lungs, where they are arrested in the capillaries, although some may pass through into the arterial circulation and reach other organs like the spleen and kidneys and even the fœtus in a pregnant animal. The majority of the larvæ escape from the lung capillaries into the alveoli, where they grow and moult. From about 7 to 23 days after infection the larvæ migrate up the trachea to the pharynx and pass down the œsophagus to the intestine, where they grow adult in 8-9 weeks. The larvæ found in the lungs are 0·7-1·5 mm. long.

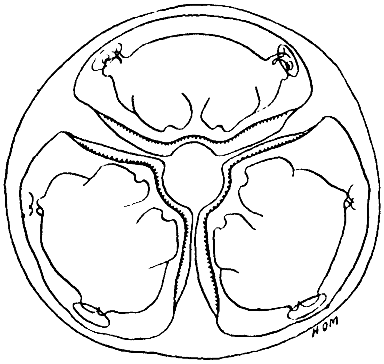

FIG. 83.—*Ascaris lumbricoides*, ANTERIOR VIEW OF HEAD. (ORIGINAL.)

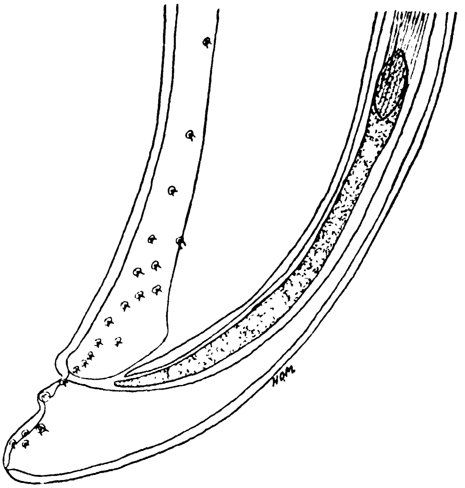

FIG. 84.—*Ascaris lumbricoides*, HIND END OF MALE, LATERAL VIEW, SHOWING ONE SPICULE. (ORIGINAL.)

The infective eggs of various ascarids will hatch in the intestine of many vertebrates and the larvæ migrate through the lungs, but do not grow adult in the intestine if the host is unsuitable. Ortlepp has shown that eggs of ascarids from snakes will hatch in the intestine of mice and the migration through the lungs takes place even in these animals. In this way infective eggs of the pig *Ascaris* may be dangerous to man and other animals.

Pathogenesis.—During the migratory period the larvæ are able to do much damage if the infection is heavy. Destruction of tissue and hæmorrhage may occur in the liver, especially around the intralobular veins, but the most important lesions are produced in the lungs, where the larvæ cause numerous small hæmorrhages into the alveoli and bronchioles, followed by desquamation of the alveolar epithelium, œdema and infiltration of the surrounding pulmonary parenchyma with eosinophiles and other cells. Secondary bacterial invasion of the weakened lung tissue may lead to lobar pneumonia. Larvæ which find their way into the general circulation may cause small hæmorrhages in important organs like the brain, myocard and kidneys, but some of the lesions caused in these organs are probably due to toxins.

The adult parasites in the intestine feed on the contents and also gnaw at the mucosa, producing superficial ulcers into which infection may enter. The worms may be so numerous or they may become twisted into bundles in such a way that intestinal obstruction occurs. Ascarids have the habit of wandering about and they may enter the stomach and be vomited, or wander up the bile duct into the liver, causing biliary stasis, or they may even perforate the intestine and produce peritonitis. Ascarids that die and are digested liberate substances which are exceedingly harmful to the host.

Symptoms.—The symptoms of ascariasis in pigs depend on the severity of the infection. Chiefly young pigs are affected. New-born pigs which become heavily infected may show symptoms of pneumonia, especially a cough and exudate. They usually creep into dark corners or under the straw and die about a week after infection. In less severe cases the animals cough and their growth is stunted. Nervous symptoms are occasionally observed in older animals. Various complications may occur, as indicated in the pathogenesis. Toxic lesions in the kidneys may lead to necrosis of the tubular epithelium and the presence of casts in the urine.

Post-Mortem.—Varying degrees of pneumonia or bronchitis may be found or only a number of petechial hæmorrhages in the lungs. The larvæ can be found by pressing small bits of lung tissue between two slides and examining under a low magnification, or by teasing up portions of the organ in warm saline. Small hæmorrhagic or necrotic foci may also be seen in other organs. In the intestine worms of various ages may be found and some may have become lodged in the bile ducts.

Diagnosis.—During the early stages of the disease the pulmonary symptoms will indicate the possible ætiological factor and larvæ may be found in the sputum. *Ascaris* eggs will be found in the fæces of the older pigs or in the soil on which the animals are kept. Rarely an animal may harbour a few male worms only, in which case no eggs will, of course, be found in the fæces. Unfertilised eggs are frequently seen, and they are significant when only female worms are present or when egg counts are made. Apparently fertilisation has to be repeated at intervals and unfertilised eggs may be laid even when males are present. Such eggs are variable in shape, elongate or triangular, and contain numerous vacuoles and large granules.

Treatment.—It has been shown that santonin, which was formerly frequently employed, is not sufficiently effective and may be useful only in small, repeated doses. The best results are obtained by the administration of oil of chenopodium at the rate of 0·1 c.c. per kilo live weight (about 1 dram per 100 lbs.), with a maximum of 12 c.c. in a large dose of castor oil, after fasting for a suitable period. Hexylresorcinol (see p. 144) may be useful, but is expensive. Phenothiazine (see p. 171) is fairly effective.

Prophylaxis.—Owing to the resistance and longevity of the eggs it is not feasible to disinfect a plot on which infected pigs have been kept. The animals should be removed to a temporary enclosure for treatment and transferred to fresh ground within 10 days, before any eggs passed by them can have become infective. Sties with concrete floors can be kept relatively clean by scrubbing out with boiling water and soda every 10 days or longer, depending on the temperature.

The most important preventive measures are those concerned with the protection of the young pigs immediately after birth. A very satisfactory system, which was devised by Ransom in America, is known as the MacLean County System. The sow is thoroughly washed and scrubbed just before farrowing in order to remove any eggs adhering to the body, and is then placed in the farrowing pen. The latter has a concrete floor and has been prepared by thoroughly scrubbing the floor and walls with boiling water, soda and a hard broom. Within 10 days of farrowing the sow and her litter are carted to a clean field planted with rape or other suitable crop. After weaning the sow is removed and the young pigs grow up in safety. The sow should be treated for *Ascaris* at a suitable time before farrowing.

Ascaris eggs may be spread about by fowls, dogs and many insects, and suitable control measures should be instituted where such factors may operate.

A. vitulorum Goeze, 1782, occurs in the small intestine of cattle, zebu and the Indian buffalo, and is found in many parts of the world. The males measure up to 25 cm. by 5 mm. and the females 30 cm. by 6 mm. The cuticle is not as thick as in other large ascarids, and these worms therefore have a soft, translucent appearance. The body does not taper much towards the extremities. There are three lips, broad at the base and narrow anteriorly. The œsophagus is 3-4·5 mm. long and has a posterior, granular ventriculus. The tail of the male usually forms a small spike-like appendage. There are about five pairs of postcloacal papillæ; the anterior pair is large and double. The precloacal papillæ are variable in number. The spicules are 0·95-1·25 mm. long. The vulva is situated about one-eighth of the body length from the anterior end. The eggs are subglobular, provided with a finely pitted albuminous layer and measure 75-95 by 60-75 μ.

Life-Cycle.—Similar to that of *A. lumbricoides.*

Pathogenicity and Symptoms.—In some localities this parasite is very common in sucking calves, producing loss of appetite, unthriftiness and a tendency to diarrhœa and colic. The animals become dull and easily exhausted. They have a staring coat and frequently the conjunctiva is pale. An unusual smell resembling that of fresh ascarids may be noticed about the animals.

Diagnosis can be made by finding the eggs in the fæces.

Treatment.—No very satisfactory remedy is known. Usually turpentine in doses of 4-8 c.c., mixed with 60 c.c. each of raw linseed and castor oil, is administered on two successive mornings, with fairly good results. Chenopodium oil should be tried.

Prophylaxis.—Regular treatment of infected animals should be combined with hygienic conditions for the calves. They should not be kept in pens, but in a spacious, well-drained paddock.

A. equorum Goeze, 1782 (syn. *A. megalocephala*, *Parascaris equorum*), occurs in the small intestine of equines, including the zebra, and perhaps also cattle. The males are 15-28 cm. long and the females up to 50 cm. by 8 mm. This is a rigid, stout worm with a large head. The three main lips are separated by three small intermediate lips and are divided into anterior and posterior portions by horizontal grooves on their medial surfaces. The male tail has small lateral alæ. There are two double and three single pairs of postcloacal papillæ, a large number of precloacal paired papillæ and a single papilla on the anterior border of the cloaca. The spicules are about 2-2·5 mm. long. The vulva is situated at the end of the first quarter of the body. The eggs are subglobular with a thick, pitted albuminous layer and measure 90-100 μ in diameter.

Life-Cycle.—Similar to that of *A. lumbricoides.* The worms grow adult in about 12 weeks after infection.

Pathogenicity and Symptoms.—Especially foals suffer from this parasite. In the early stages an elevated temperature and a cough may be noticed. Later the animals become unthrifty and easily exhausted, the coat is harsh and there are frequently digestive disturbances and symptoms of colic. Intestinal obstruction and even perforation may occur.

Diagnosis can be made by finding the eggs in the fæces. They can be readily distinguished from the eggs of other equine worms.

Treatment.—After fasting for 18 hours, carbon bisulphide is administered by stomach tube or in capsule at the rate of 5 c.c. per 100 kilos (6 drams per 1,000 lbs. or more). A purgative should not be given, as superpurgation may be caused. The worms are passed for several days after treatment. The drug frequently produces a slight inflammation in the stomach, but this is of no consequence. Carbon tetrachloride, as administered for blood-sucking strongyles, also removes a fair proportion of ascarids, but oil of chenopodium is not sufficiently effective against this parasite.

Prophylaxis.—Attention should be paid to the young foals at the time of birth, as in the case of pigs, and the foal should run with its mother in a clean paddock. Stables should be cleaned frequently, and clean water and food supplied in such a way that contamination is not likely to occur. Manure disposal plays an important part, since it is known that practically all worm eggs and larvæ will be killed by the heat generated during fermentation of the manure (see p. 319).

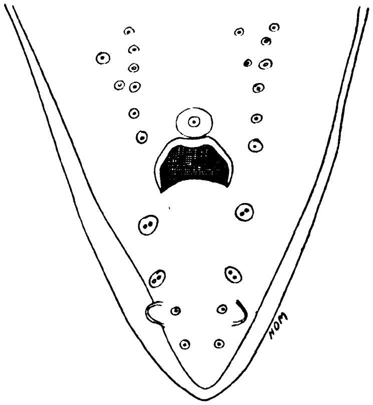

FIG. 85.—*Ascaris equorum*, HIND END OF MALE, VENTRAL VIEW. (ORIGINAL.)

A. columnaris Leidy, 1856, occurs in the small intestine of the skunk, stoat, weasel and the Siberian polecat (*Putorius eversmanni*). The males are up to 9 cm. and the females up to 22·5 cm. long. There are three lips, the dorsal bearing two single papillæ and the ventrals one each. The cloaca of the male is surrounded by granular, roughened areas. Of the postcloacal papillæ, the anterior pair is double and further back there are five pairs, of which the anterior two are usually placed close together. The spicules are about 0·4 mm. long. The vulva is situated at the end of the first quarter of the body. The eggs have finely pitted shells and are subglobular, measuring 88-90 by 66-68 μ.

Life-Cycle.—Similar to that of *A. lumbricoides*, according to Goodey and Cameron.

Genus **Toxascaris** Leiper, 1907

T. leonina (v. Linstow, 1902) (syn *T. limbata*) occurs in the small intestine of the dog, cat, fox and wild *Canidæ* and *Felidæ* in most parts of the world. The males are up to 7 cm. long and the females up to 10 cm. The anterior part of the body is provided with large cervical alæ and is bent dorsad. The female genital organs lie behind the level of the vulva. The tail of the male is simple and the spicules are 0·7-1·5 mm. long. The eggs are slightly oval, with smooth shells, and measure 75-85 by 60-75 μ.

Life-Cycle.—The eggs contain fully developed larvæ in 3 days under optimal conditions. They hatch after having been swallowed by the host and the larvæ penetrate into the mucosa of the intestine, mainly the posterior part of the duodenum, where they develop for some time. Migration through the lungs rarely occurs.

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Genus **Toxocara** Stiles, 1905

T. canis (Werner, 1782) (syn. *Belascaris marginata*) occurs in the small intestine of the dog and fox. It is larger than the previous species, the males being up to 9 cm. long and the females up to 17 cm. Large cervical alæ are present and the body is anteriorly bent ventrad. The female genital organs extend anteriorly and posteriorly to the vulvar region. The male tail has a terminal narrow appendage and caudal alæ. The spicules are 0·73-0·93 mm. long. The eggs are subglobular, with thick, finely pitted shells, and measure about 90 by 75 μ.

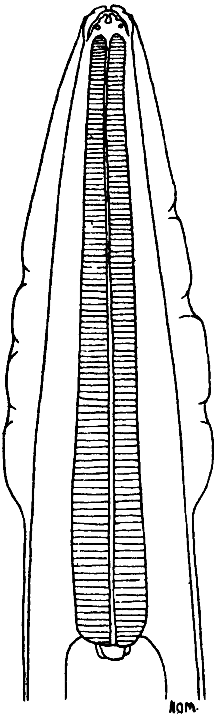

FIG. 86. — *Toxocara canis*, ANTERIOR END, DORSAL VIEW. (ORIGINAL.)

Life-Cycle.—Similar to that of *A. lumbricoides*, including migration through the lungs. The eggs contain fully developed larvæ in 5 days under optimal conditions.

T. mystax (Zeder, 1800) occurs in the small intestine of the cat and wild *Felidæ*. The spicules are 1·63-2·08 mm. long.

ASCARIASIS IN DOGS, CATS AND FUR-BEARING ANIMALS

Pathogenesis.—Young animals are chiefly affected and the intra-uterine infection of pups by larvæ of *T. canis*, which pass through the lung capillaries of the mother, is an important factor. Such larvæ remain in the liver of the fœtus until the latter is born and begins to breathe, when they continue their migration through the lungs.

As in the case of *Ascaris lumbricoides*, the host may be affected by larvæ migrating through the lungs or by the adult worms in the intestine. Intestinal obstruction is common, and, although it may be only temporary, it frequently causes decreased peristalsis, a fact which is important, especially in connection with treatment by means of drugs like oil of chenopodium. The worms may migrate into the bile ducts, causing biliary stasis and icterus. Worms that die and are digested liberate toxic products which are very harmful to the host.

Symptoms.—The animals are unthrifty and either pot-bellied or the abdomen is tucked up, the coat is dull and harsh, there is usually emaciation, often anæmia, restlessness and diarrhœa or constipation. Nervous symptoms of various kinds may be seen, even such as may lead to a suspicion of rabies. Death due to acute intestinal obstruction is not infrequent.* In the case of foxes the most dangerous period is during the first few weeks of life, especially from the second to the fourth. Extreme pot-belliedness of fox pups, which is not infrequent, indicates the presence of ascarids in the peritoneal cavity, the worms having reached this situation during migration.†

Diagnosis is made by finding the eggs in the fæces. Sprehn‡ states that the females lay their eggs in cycles lasting 2-3 weeks and that in the intervals no eggs may be found in the fæces. This may be due to the apparent necessity of repeated fertilisation in ascarids, mentioned above, and is important in connection with diagnosis.

Treatment is carried out after a suitable short period of starvation. Chenopodium oil at the rate of 0·1 c.c. per kilo, given in or followed by a large dose of castor oil, produces excellent results. In heavy infections, when peristalsis may be decreased, this drug is dangerous, as it may not be passed rapidly enough through the intestine to prevent absorption. For such cases tetrachlorethylene is indicated. This drug is used for preference in the treatment of foxes, young dogs and cats. It is administered in a dose of 0·2-0·3 c.c. per kilo in a gelatin capsule. Care should be taken that the capsule is properly swallowed, for if it is broken in the mouth asphyxiation may take place. In such a case the capsule must be quickly removed, the animal is swung round a few times by the hind legs and artificial respiration is then applied. Sprehn* states that capsules dipped in honey are readily taken by foxes. Fox pups should be treated when they are 2-3 weeks old and again 10-14 days later, to expel worms that were migrating through the body at the time of the first treatment.

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* Hanson, *Journ. Amer. Vet. Med. Assn.*, n.s., 33 (2): 201-212. 1932. Sprehn, *Deut. Tier. Wschr.*, 36 (46): 763-767. 1928.

† *Berl. Tier. Wschr.*, 48 (13). 1932. ‡ *Tier. Rdsch.*, 38 (23 and 24). 1932.

Hexylresorcinol was introduced by Lamson† and his associates and gives very promising results as an ascaricide. It is a white crystalline substance, rather insoluble in water, which precipitates protein; it is therefore somewhat irritating to the mucosa of the stomach and intestine and must be administered after proper starvation. About 30 per cent. of the drug is absorbed and very rapidly excreted by the kidneys, the rest being passed in the fæces, and no cases of intoxication are so far known. It has a blistering or corrosive action on the cuticle of the nematode. The drug is too irritating on the buccal mucosa to be administered as a powder, it is ineffective when given in oil and it decomposes gelatin capsules. It is therefore administered in sugar-coated pills or in freshly filled hard gelatin capsules. The dose for human beings is 0·1 gm. per year of age up to 1 gm. Dogs can receive 1 gm. per 10 kilos or over.

Prophylaxis.—Since the infection is acquired by animals kept in a confined space rather than by those running on open ground, and in the case of foxes especially when they are kept in boxes, prevention is a matter of hygiene. After treatment all worms expelled should be removed at frequent intervals. Boxes and kennels should be kept clean and as dry as possible. Sprehn recommends an iodine preparation, " Viscojod," which is used in Germany for the disinfection of fox boxes, rather than washing with water and other disinfectants. Vitamin deficiency and other conditions such as rickets especially, which lower the resistance of the animal, predispose strongly to ascariasis and should be guarded against.

Sub-Family ANISAKINÆ

In this sub-family of the *Ascaridæ* the œsophagus is provided with one or more of the following accessory structures: a muscular bulb, a posterior ventriculus of granular structure, frequently a cæcum arising from the anterior part of the intestine and projecting forward alongside the œsophagus, and one or more appendices of a glandular nature projecting backwards from the œsophagus. The adult worms are mainly parasites in the intestine of aquatic or fish-eating birds or reptiles, while the larvæ are found encysted in the intermuscular connective tissue of fish or other aquatic intermediate hosts.

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* *Tier. Rdsch.*, 38 (23 and 24). 1932.

† *Journ. Amer. Med. Assn.*, 99: 292-295. 1932. *Journ. Parasitol.*, 18: 173-199, 1932.

Besides **Porrocæcum crassum** (Deslongchamps, 1824), which occurs in the intestine of domestic and wild ducks, the veterinarian may at times also be concerned with the identification of the encysted larval forms in fish intended for human consumption. These cysts are usually about 1 cm. in diameter and contain the worm coiled up in a flat spiral. The characteristic structure of the œsophagus can be recognised after clearing the specimen in lactophenol.

Family HETERAKIDÆ

These are medium-sized or small worms with three lips and a small buccal capsule or pharynx. The œsophagus is usually provided with a posterior bulb. The male is provided with a circular or groove-like sucker anterior to the cloacal opening. The vulva is situated near the middle of the body. The life-cycle is usually direct and migration in the host does not take place or is confined to the wall of the intestine.

Genus **Heterakis** Dujardin, 1845

H. gallinæ (Gmelin, 1790) (syn. *H. papillosa, H. vesicularis*) occurs in the cæca of the fowl, guinea-fowl, pea-fowl, turkey, duck, goose and numerous other birds. The male is 7-13 mm. long and the female 10-15 mm. There are large lateral alæ extending some distance down the sides of the body. The œsophagus has a strong posterior bulb. The tail of the male is provided with large alæ, a prominent, circular, precloacal sucker and 12 pairs of papillæ. The spicules are unequal, the right being slender and 2 mm. long, while the left has broad alæ and measures 0·65-0·7 mm. The vulva opens directly behind the middle of the body. The eggs have thick, smooth shells; they measure 65-80 × 35-46 μ and are unsegmented when laid.

Life-Cycle.—The eggs develop in the open and reach the infective stage in 14 days or longer. They are very resistant. When the host swallows an infective egg the larva hatches in the intestine after 1-2 hours, according to Clapham,* and develops without migrating into the tissues. Baker† states that up to about the fourth day the young worms are rather closely associated with the cæcal mucosa and some injury to the glandular epithelium may occur. The first eggs are passed in the fæces of the bird after 24-30 days, or longer under certain adverse conditions. For instance, Baker found that the presence of blackhead in the host causes considerable retardation of development and fewer worms develop than in healthy birds.

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* *Journ. Helm.*, 11 (2): 67-86. 1933.

† *Scientif. Agric.*, 13 (6): 356-363. 1933.

Other species of this genus which occur in the fowl are:

H. brevispiculum Gendre, 1911.—Spicules equal, 0·4 mm. long, each with a barb near the tip.

H. indica Maplestone, 1933.—Spicules unequal, the right 0·99-1·19 mm. long with a double tip, the left 0·297-0·396 mm. The caudal alæ meet ventrally anterior to the sucker.

H. putaustralis Lane, 1914 (syn. *H. beramporia*).—Spicules sub-equal, the right 0·32-0·51, the left 0·26-0·36 mm. long, both alate, the left angulated near the tip.

H. dispar (Schrank, 1790) occurs in the goose and duck. The males are 11-18 mm. long and the females 16-23 mm.

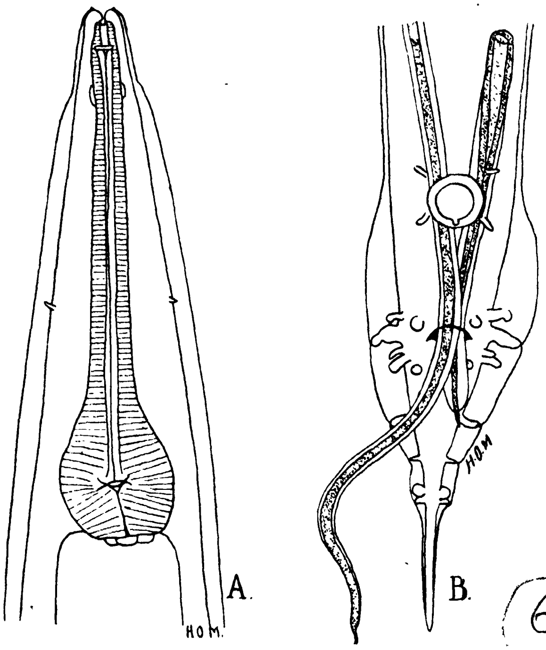

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FIG. 87.—*Heterakis gallinæ*. (ORIGINAL.)
A, Anterior end, dorsal view; B, hind end of male, ventral view.

Pathogenicity and Symptoms.—The parasites may casue a typhlitis resulting in diarrhœa and loss of condition, but such symptoms are not frequently seen, although the worms are very common in many parts of the world. *H. gallinæ* may be associated with a disease, known as "blackhead," in turkeys and fowls. The protozoan *Histomonas meleagridis,* which causes blackhead, may occur within the *Heterakis* eggs, and the symptoms of the disease may be shown by birds 2-3 weeks after they have come on to ground infected with *Heterakis* eggs or after experimental infection with the eggs.

The young parasitic stages of *H. putaustralis* cause the formation of nodules in the walls of the intestinal cæca, according to Schwartz.

Diagnosis is made by finding the eggs in the fæces. As has been explained in the chapter on technique, cæcal fæces have to be examined and the eggs must be differentiated from those of *Ascaridia galli* and other related worms.

Treatment and Prophylaxis.—Phenothiazine (see p. 171) is effective.

Genus **Ascaridia** Dujardin, 1845

A. galli (Schrank, 1788) (syn. *A. lineata, A. perspicillum*) occurs in the small intestine of the fowl, guinea-fowl, turkey, goose, and various wild birds in most parts of the world. Male 50-76 mm., female 72-116 mm. long. There are three large lips and the œsophagus has no posterior bulb. The tail of the male has small alæ and bears ten pairs of papillæ, most of which are short and thick. There is a circular precloacal sucker with a thick cuticular rim. The spicules are subequal, 1-2·4 mm. long. The vulva is situated a short distance anterior to the middle of the body. The eggs are oval, with smooth shells, and are unsegmented when laid. They measure 73-92 by 45-57 μ.

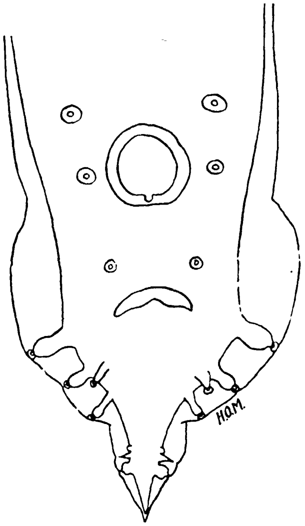

FIG. 88.—*Ascaridia galli*, HIND END OF MALE, VENTRAL VIEW. (ORIGINAL.)

Life-Cycle.—The eggs are passed in the fæces of the host and develop in the open, reaching the infective stage in about 10 days, or longer when the temperature is low. The egg then contains a fully developed larva and is fairly resistant to adverse conditions. According to Ackert, the eggs can remain viable for over 3 months in shaded places, but are rapidly killed by dry, hot weather, even when they are 6 inches deep under the soil exposed to sunlight. Infection takes place by ingestion of the eggs with food or water. Earthworms may ingest the eggs and, when they are swallowed by the birds, transmit the infection in a mechanical way.

The eggs hatch in the intestine of the host and the larvæ penetrate into the duodenal mucosa after about 10 days, according to Ackert,* returning to the lumen 7 days later. The worms grow adult in 5-8 weeks. Only exceptionally does a larva migrate through the lungs, as in the case of *Ascaris lumbricoides*.

Pathogenicity.—Young birds are more susceptible to infection than adult birds or others that have had a previous infection. Deficiency of vitamins A and B predisposes to infection. The worms are able to cause marked symptoms in young birds, but when the infection has been overcome the birds may recover rapidly.

Pathogenesis and Symptoms.—Marked lesions may be produced when large numbers of the young parasites penetrate into the duodenal mucosa. They cause hæmorrhage and enteritis and the birds become anæmic and suffer from diarrhœa. Toxic substances are perhaps produced by the worms, since the birds become unthrifty, markedly emaciated, generally weak or sometimes paretic and egg production is decreased. In heavy infections intestinal obstruction may occur. The appetite is at first decreased, but later the birds may become voracious.

Post-Mortem.—About a fortnight after infection a hæmorrhagic enteritis may be seen without any obvious cause. In such cases the duodenal mucosa has to be examined for the presence of the larval worms, which are then about 7 mm. long. In other cases the carcass is emaciated and anæmic and the worms are found in the intestine.

Diagnosis can be made by finding the eggs in the fæces or the worms in the intestine at autopsy. In the latter case the parasites have to be differentiated especially from *Hartertia gallinarum* (p. 236).

Treatment.—After fasting overnight the birds are treated with oil of chenopodium, 4 drops per kilo live weight, given in 3-4 c.c. olive or raw linseed oil. Other suitable drugs are carbon tetrachloride and tetrachlorethylene in doses of 1-2 c.c. with oil to make 5 c.c. Nicotine compounds in the form of pills and colloidal iodine preparations are coming into use and may be very effective. Rebrassier recommends 2 gm. pyrethrum, containing 0·8 per cent. pyrethrin, in gelatin capsule. Although individual treatment is more effective than mass treatment, the latter is sometimes useful. The following method gives good results: Into the mash is mixed 2 per cent. by weight of tobacco dust, and this is fed daily for a month whenever necessary. The tobacco should contain about 2 per cent. nicotine. Too little is ineffective and too much decreases the egg yield.

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* *Parasitology*, 23 (3): 360-379. 1931.

Prophylaxis.—Special attention should be paid to the young birds. The infection is more frequent in birds kept in a confined space than in those running free. If possible the run should therefore be large and the soil kept dry and not unduly shaded. Occasionally a lime dressing may be applied and the soil dug over. Droppings must be regularly removed. Food and water have to be supplied free from infection. Proper feeding, especially food containing the required vitamins, is important. It is advisable, as a general rule, to remove all chicks that would be susceptible to worm infection on account of a weak constitution.

A. columbæ (Gmelin, 1790) (syn. *A. maculosa*) occurs in domestic and wild pigeons. It is a large worm like the previous species, but apparently not very pathogenic. For treatment 0·25 c.c. carbon tetrachloride or 0·5 c.c. of 25 per cent. oil of chenopodium in castor oil, given in a gelatin capsule after starvation overnight, and repeated after 7 days, is recommended by Baudet.

Genus Subulura

S. brumpti (Lopez Neyra, 1922) occurs in the cæca of the fowl, turkey, guinea-fowl and wild related birds in Africa, South America and Spain. The males are 6·9-10 mm. long and the females 9-17·5 mm. Lateral alæ are present. The small buccal capsule has three teeth at its base. The œsophagus has a small swelling posteriorly, followed by

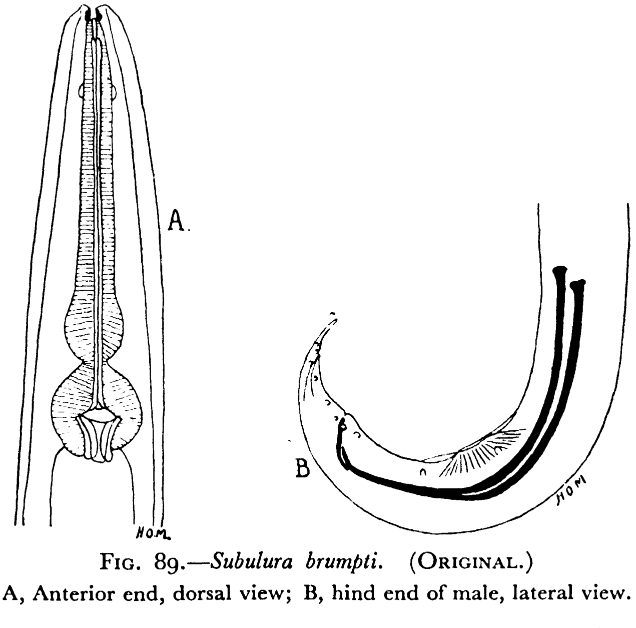

FIG. 89.—*Subulura brumpti.* (ORIGINAL.)
A, Anterior end, dorsal view; B, hind end of male, lateral view.

a deep constriction and then a spherical bulb. The tail of the male is provided with large lateral alæ and is curved ventrad. The precloacal sucker is an elongate slit, surrounded by radiating muscle fibres. There are ten pairs of small caudal papillæ. The spicules are equal, alate and 1·3-1·5 mm. long. The vulva is situated just anterior to the middle of the body. The eggs are subglobular with smooth shells, and contain a fully developed embryo when laid. They measure 52-64 by 41-49 μ.

Life-Cycle.—The intermediate hosts are various beetles, Dermaptera and Orthoptera according to Alicata.

Pathogenicity.—Apparently not marked.

Treatment.—As for *Heterakis gallinæ.*

S. differens (Sonsino, 1890) is a similar form occurring in the fowl and guinea-fowl in Southern Europe, Africa and Brazil.

Family KATHLANIIDÆ

This family contains only one species of veterinary interest, *Probstmayria vivipara* (Probstmayr, 1865), a small worm living in the colon of equines. The worms are 2-2·9 mm. long. The females are viviparous and give birth to larvæ which are almost as large as the adults. It is believed that this worm represents a unique example of multiplication of a nematode in the body of the host. Probably as a result of this method of reproduction, the infections found are usually enormous, but the worms are not known to be pathogenic.

Family OXYURIDÆ

These are medium-sized or small worms with three inconspicuous lips. The œsophagus has a well-developed bulb. The male bears a number of large papillæ around the cloacal opening. The females are usually much larger than the males and have long, tapering tails. The vulva is situated near the anterior end of the body. The eggs are usually flattened on one side and development takes place without an intermediate host.

⑥

Genus Oxyuris, Rudolphi, 1803

O. equi (Schrank, 1788) (syn. *O. curvula, O. mastigodes*) occurs in the large intestine of equines in all parts of the world. The male is 9-12 mm. long and the female up to 150 mm. The œsophagus is narrow at the middle and the bulb is not distinctly marked off. The male has one pin-shaped spicule which is 0·12-0·165 mm. long and the tail bears two pairs of large and a few small papillæ. The young females are almost white in colour, slightly curved and have relatively short, pointed tails. The mature females have a slaty-grey or brownish colour and narrow tails which may be more than three times as long as the rest of the body.

The eggs are elongate, slightly flattened on one side, provided with an operculum at one pole, and measure about 90 by 42 μ.

Life-Cycle.—The males and young females inhabit the cæcum and large colon. After fertilisation the mature females wander down to the rectum and crawl out through the anal opening with the anterior parts of their bodies. The eggs are laid in clusters on the skin in the perineal region. Development of the embryo proceeds rapidly and the eggs drop off after about 3 days, when they contain infective larvæ. The eggs are ingested by the horses with food or water.

Pathogenesis.—It has been shown by Wetzel that the fourth stage larva of this parasite feeds on the intestinal mucosa of the host. The adult worms are, however, not found attached and probably feed on the intestinal contents. The chief feature of oxyuriasis in equines is the anal pruritus produced by the egg-laying females.

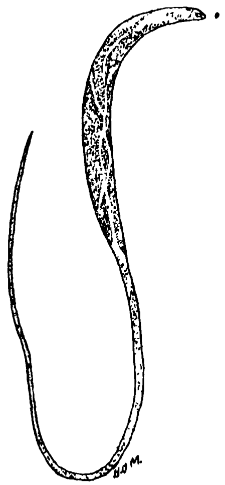

Fig. 90.—*Oxyuris equi*, Female, Natural Size. (Original.)

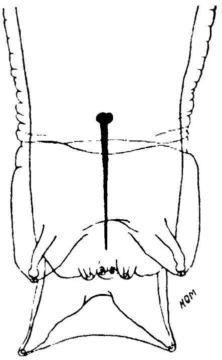

Fig. 91.—*Oxyuris equi*, Hind End of Male, Ventral View. (Original.)

Symptoms.—The irritation caused by the pruritus produces restlessness and improper feeding, which results in loss of condition and a dull coat. The animal rubs the base of its tail against any suitable object, causing the hairs to break off and the tail to acquire an ungroomed appearance.

Diagnosis.—The symptoms should lead to an examination of the perineal region, where cream-coloured masses of eggs will be found. These should be removed and identified under the microscope. The condition can in this way be differentiated from mange and anal pruritus due to other causes.

Treatment and Prophylaxis.—After starving for 36 hours the animal is dosed with oil of chenopodium at the rate of 3·5 c.c. per 100 kilos (4 drams per 1,000 lbs.)* in a litre of raw linseed oil. In order to remove the mature females an enema of strong quassia infusion may be given. To relieve the pruritus and to kill any adhering eggs mercuric or carbolic ointment may be applied. The stable should be thoroughly cleaned, fresh bedding supplied at short intervals and the food and water kept free from contamination.

Genus **Passalurus** Dujardin, 1845

P. ambiguus (Rudolphi, 1819) occurs in the cæcum and the colon of rabbits, hares and other rodents. Male 4·3-5 mm., female 9-11 mm. long. The lips are inconspicuous and the cervical alæ are small. The œsophagus has a prebulbar swelling and a strong bulb. The male tail has a whip-like appendix and small caudal alæ supported by papillæ. The spicule is simple and 0·09-0·12 mm. long. The female has a tapering tail 3·4-4·5 mm. long and the cuticle of its distal extremity is marked with about 40 circular striations. The vulva opens 1·54-1·89 mm. from the anterior extremity. The eggs are flattened on one side and measure 95-103 by 43 μ.

Life-Cycle.—Development is direct and infection occurs through the ingestion of infective eggs. The young stages are found in the mucosa of the small intestine and the cæcum.

Pathogenicity, etc.—These worms sometimes occur in enormous numbers in young rabbits, but appear to be relatively harmless.

Genus **Skrjabinema** Vereschagin, 1926

This genus contains several species of small worms measuring about 3-8 mm. in length, which occur in the cæca of ruminants. They have three large, complicated lips and three small intermediate lips.

S. ovis (Skrjabin, 1915) has been found in the sheep, goat and antelopes in several countries, and *S. alata* Mönnig, 1932, in the sheep in South Africa. These worms are apparently not pathogenic, but may be mistaken for young forms of other nematodes, like *Œsophagostomum columbianum.*

Family RHABDITIDÆ

Small worms, mostly free-living. There is a small buccal cavity and the œsophagus usually consists of an anterior wide portion followed by a shorter, narrow portion and then a spherical bulb. This type of œsophagus is known as " rhabditiform " and is seen in the first-stage larvæ of many nematodes. The reproductive organs are simple and some forms are parthenogenetic. The females are oviparous or viviparous and the life-cycle is direct. .

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* A smaller dose should be given to thoroughbred horses; see under Strongylidosis.

Genus **Rhabditis** Dujardin, 1845

R. strongyloides (Leuckart, 1883) is a free-living nematode which may in rare cases invade the skin, but probably only when the latter is already damaged. Chitwood* describes the affection in a dog. The skin of the affected areas is red, denuded, partly covered with crusts, and there are pustules surrounded by red zones, as well as nodules. The pustules contain typical *Rhabditis* larvæ, 596-600 μ long.

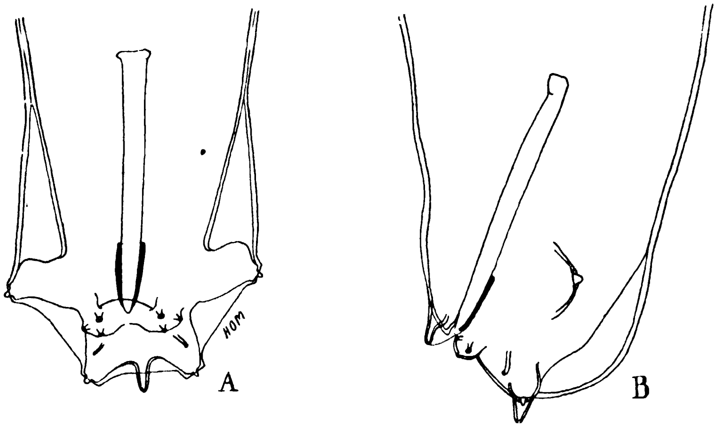

FIG. 92.—*Skrjabinema ovis*, HIND END OF MALE. (ORIGINAL.)
A, Ventral view; B, lateral view.

Genus **Strongyloides** Grassi, 1879

This genus contains several species which live partly as parasites in domestic animals. The parasitic forms are parthenogenetic and their eggs may give rise, outside the host, to infective larvæ directly or to a free-living generation of minute males and females, which again produce infective larvæ. The latter are able to penetrate through the skin of the host and pass with the blood to the lungs, thence up the trachea to the pharynx and on to the intestine. The adult worms are characterised by their female genital organs and by the relatively long œsophagus.

S. papillosus (Wedl, 1856) occurs in the small intestine of the sheep, goat, cattle, rabbit and wild ruminants. Similar worms have been found in various fur-bearing animals, including the mink. It is 3·5-6 mm. long and 0·05-0·06 mm. thick. The œsophagus is 0·65-0·8 mm. long. The eggs have rather blunt ends and thin shells. They measure 40-60 by 20-25 μ and contain fully developed embryos when passed in the fæces of the host.

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* *North Amer. Vet.*, June, 1932.

S. westeri Ihle, 1917, occurs in the small intestine of the horse, pig and zebra. It is up to 9 mm. long and 0·08-0·095 mm. thick. The œsophagus is 1·2-1·5 mm. long and the eggs measure 40-52 by 32-40 μ.

S. stercoralis (Bavay, 1876) occurs in the small intestine of man, dog, fox and cat. It is about 2·2 mm. long and 0·034 mm. thick. The œsophagus is 0·6 mm. long. The eggs measure 50-58 by 30-34 μ, but usually rhabditiform larvæ are found in fresh fæces.

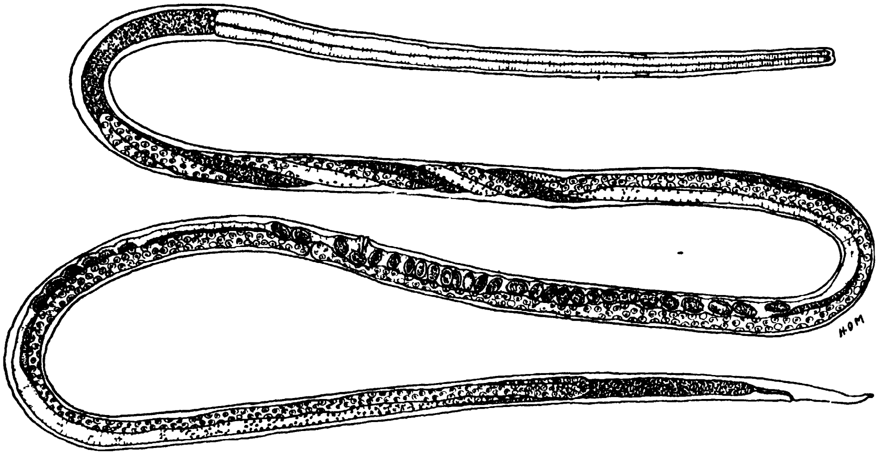

Fig. 93.—*Strongyloides westeri*, Female. (Original.)

S. cati Rogers, 1939, occurs in the small intestine of the cat. It is 2·37-3·33 mm. long. The eggs measure 57·6-64 by 23-40 μ and are poorly developed when passed in the fæces.

S. ransomi Schwartz and Alicata, 1930,* occurs in the small intestine of the pig. It is 3·33-4·49 mm. long. The eggs measure 45-55 by 26-35 μ.

S. suis is also found in this host. It is 4-6 mm. long and the eggs measure about 60 by 40 μ.

S. avium Cram, 1929,† occurs in the small intestine and the cæca of the fowl, turkey and some wild birds. It is 2·2 mm. long. The œsophagus is 0·7 mm. long and the eggs measure 52-56 by 36-40 μ.

Life-Cycle.—As described above. In some species the eggs are laid in strings. In the case of *S. papillosus* infection may occur through the skin, but probably it often occurs per os. The infective or "filariform" larvæ of *Strongyloides* have no sheath and are not resistant to desiccation. The œsophagus is longer than one-third of the body and the tail is bifid at its extremity. *S. westeri* penetrates through the skin of the horse, passing through the hair follicles or small abrasions, according to Baudet.*

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* *Journ. Agr. Res.*, 40: 11-23. 1930.

† *North Amer. Vet.*, 10 (8): 27-30. 1929.

Pathogenicity and Symptoms.—The worms penetrate into the mucosa of the intestine, but are on the whole not very pathogenic, especially *S. papillosus* in sheep; in mink, however, it is stated to be markedly pathogenic. The other species may cause enteritis and diarrhœa when the infection is severe. *S. westeri* is found chiefly in foals and may cause diarrhœa. *S. avium* produces a marked thickening and inflammation of the walls of the cæca. *S. stercoralis* is the cause of a very persistent diarrhœa in man in warm countries and may affect dogs in a similar way. Young pigs may become weak and stunted in growth from *Strongyloides* infection. According to Beveridge, the larvæ of *S. papillosus* penetrating through the skin of the feet of sheep are an important factor in the introduction of the necrosis bacillus which causes foot-rot.

Diagnosis is made by finding the characteristic eggs or larvæ in the fæces.

Treatment.—No very satisfactory treatment is known for these parasites. It is stated that *S. westeri* is very susceptible to the effects of arsenic and that liquor arsenicalis, given for about 10 days, produces satisfactory results. *S. papillosus* appears to be extremely resistant to drugs, including arsenical and other anthelmintics. For mink and coypu Sprehn recommends tetrachlorethylene, 0·3 c.c. per kilo bodyweight. According to Faust, gentian violet appears to be effective against *Strongyloides* and should be tried on domestic animals when treatment is indicated. Hexylresorcinol may also be useful.

Prophylaxis.—Since the infective larvæ are not resistant to desiccation, the infection can best be prevented by providing clean, dry quarters and pastures for the animals. Mink are best protected by keeping them on raised wire-netting floors.

Order TRICHINELLOIDEA

The body is more or less clearly divided into anterior and posterior portions. The anterior portion is frequently markedly narrower than the posterior and contains the long œsophagus, which has a very narrow, triradiate lumen running through a single row of cells. The anus is terminal in both sexes. The male usually has a single spicule which lies in a protrusible sheath. The vulva is situated near the junction of the two parts of the body. Life-cycle direct or with an intermediate host.

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* *Tijdschr. v. Diergeneesk.*, 57, 1-14. 1930.

Family TRICHINELLIDÆ

Genus **Trichinella** Railliet, 1895

T. spiralis (Owen, 1833) (syn. *Trichina spiralis*) occurs in the small intestine of man, pig, rat and many other mammals. Even birds have been infected experimentally. It is probably cosmopolitan in distribution, but has not been found in some countries. The male is 1·4-1·6 mm. long and the female 3-4 mm. The body is slender and the œsophageal portion is not markedly narrower than the posterior part. The hind end of the male bears a pair of lateral flaps on either side of the cloacal opening, with two pairs of papillæ between them. There is neither a spicule nor a sheath. The vulva is situated near the middle of the œsophageal region. The eggs measure 40 by 30 μ and contain fully developed embryos when laid.

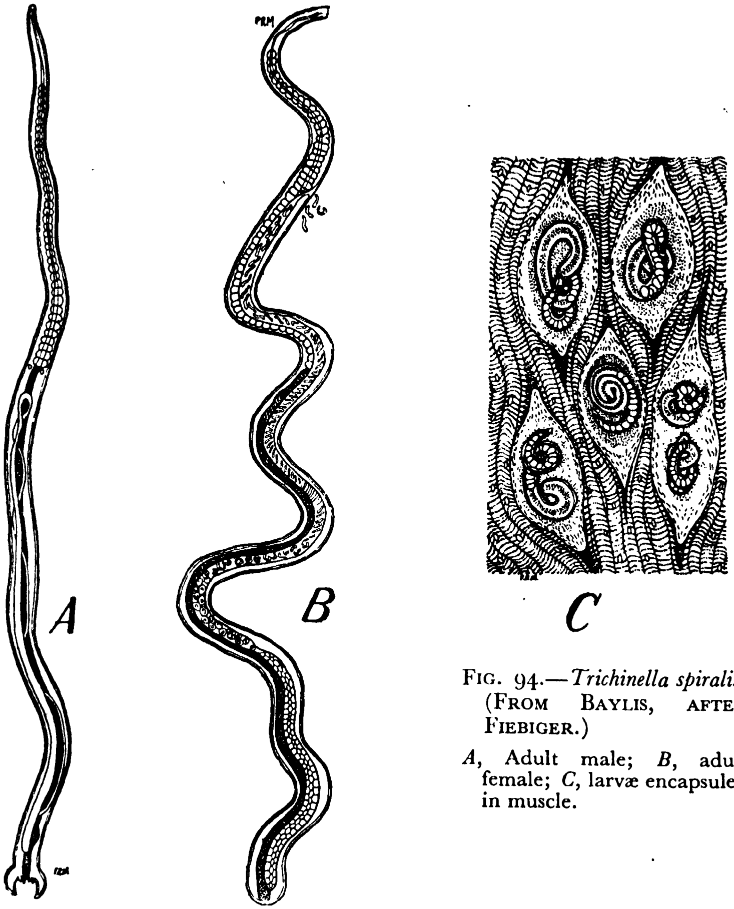

FIG. 94.—*Trichinella spiralis*. (FROM BAYLIS, AFTER FIEBIGER.)

A, Adult male; *B*, adult female; *C*, larvæ encapsuled in muscle.

Life-Cycle.—After copulation has taken place in the intestine the males die and the females penetrate into the mucosa via Lieberkühn's glands until they reach the lymph spaces. Here the eggs are laid and they hatch immediately. The larvæ are distributed all over the body by the lymph and blood, developing further in the voluntary muscles, especially those of the diaphragm, tongue, larynx, eye and the masticatory and intercostal muscles. They have also been found in the liver, pancreas and kidney. The larvæ enter the muscles and grow rapidly; after 14 days they measure 0·8-1 mm. in length and lie curled up in small cysts. The cyst wall is fully formed after about 3 months and measures 0·4-0·6 by 0·25 mm. The affected muscle fibres degenerate and the cysts usually begin to calcify after 6-9 months, but the larvæ in them may live for several years. Cases in which the larvæ lived for 11 and even 24 years have been recorded. The infection is passed on to another host which ingests meat containing viable larvæ. The latter are liberated from their cysts in the stomach and grow adult in the intestine, beginning to deposit larvæ within 6-7 days. The females live for about 6 weeks and each gives birth to some 1,500 larvæ. Several authors unsuccessfully attempted to produce prenatal infection with this parasite, but Roth* found a small percentage of fœtal guinea-pigs infected after heavily infecting the pregnant mothers.

Pathogenesis and Symptoms.—The intestinal forms may produce a certain amount of irritation and cause a marked enteritis in heavy infections. The most important pathogenic effects are produced by the larvæ in the muscles. Heavy infections may lead to death, especially through paralysis of the respiratory muscles. The symptoms which accompany trichinosis are diarrhœa, fever, stiffness and pain in the affected muscles, dyspnœa, hoarseness, sometimes an œdema of the face and deafness. A marked eosinophilia is usually present. The worms apparently produce a toxin, since the serum of affected animals is toxic when injected into susceptible animals. A crisis is usually reached after about 4 weeks, when the egg-production of the females begins to decline and the larvæ become encapsulated. So-called epidemics of trichinosis occasionally occur in human beings where a number of people partake of insufficiently cooked trichinous meat of a pig or bear.

Diagnosis.—The adult worms may sometimes be found in the fæces or the larvæ in the blood, but this is rather accidental than the rule. Augustine and Theiler† found that intradermal tests with high dilutions of antigen are specific and reliable, especially if coupled with precipitin tests. The production of an antigen and the technique of the test are described by Bozicevich* and by McNaught, Beard and Myers.† Small bits of affected muscle may be removed for examination, but the diagnosis in animals is usually made after death by microscopic examination of muscle pressed flat between glass slides. Special "trichinoscopes" are used in some abattoirs for the rapid examination of specimens from a large number of carcasses. More accurate results are obtained by digesting larger samples of meat by means of papain, as described by Lyster.‡

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* *Zentralbl. f. Bact.*, I, Orig., 136 (5/6): 278-284. 1936.

† *Parasitol.*, 24 (1): 60-86. 1932.

Treatment and Prophylaxis.—No satisfactory method of treatment is known. Where the disease is diagnosed the larvæ will be entering the muscles and they cannot be killed in the live animal by any known method. Formerly rats, which are cannibals and are sometimes eaten by pigs, were regarded as the chief source of infection for pigs. However, it is now definitely established that uncooked garbage which contains scraps of trichinous meat is the main source of infection. Garbage-fed pigs have trichinæ much more frequently than grain-fed pigs and, where regulations have enforced the feeding of cooked garbage only, the incidence of trichinæ has decreased markedly.

Man acquires the infection mainly from pork and sausages which are eaten raw or partly cooked, occasionally also from the meat of bears. Prophylaxis should therefore aim at the elimination of uncooked garbage in the feed of pigs and, as far as man is concerned, the thorough cooking of all pork products. Salting and other methods of curing are not reliable. Augustine has shown that the larvæ are killed by rapidly lowering the temperature of pork to – 35° C. for a short period or to – 18° C. for 24 hours. Meat inspection for trichinæ is carried out in some countries but entails much labour and expense.

Genus Trichuris Roederer, 1761 (syn. *Trichocephalus*)

The worms belonging to this genus are generally known as "whipworms," since the anterior part of the body is long and slender, while the posterior part is much thicker. The hind end of the male is curled and there is one spicule surrounded by a protrusible sheath which is usually armed with fine cuticular spines. The vulva is situated at the beginning of the wide part of the body.

T. ovis (Abildgaard, 1795) has been recorded from the cæcum of the goat, sheep, cattle and many other ruminants. The male of *T. ovis* is 50-80 mm. long; the anterior end constitutes three-quarters of the length. The female is 35-70 mm. long, of which the anterior end

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* *U.S. Publ. Health Rep.*, 53 (48): 2130-2138. 1938.

† *Amer. Journ. Clin. Path.*, 11 (3): 195-209. 1941.

‡ *Canad. Journ. Comp. Med.*, 4: 73-75. 1940.

forms two-thirds to four-fifths. The spicule is 5-6 mm. long. The sheath, when fully evaginated, bears an oblong swelling a short distance from its distal extremity and is covered with minute spines which decrease in size towards the distal extremity. The eggs are brown, barrel-shaped, with a transparent plug at either pole, and measure 70-80 by 30-42 μ, including the plugs. They contain an unsegmented embryo when laid.

T. globulosa (v. Linstow, 1901) occurs in the cæcum of the camel, sheep, goats, cattle and other ruminants, and is the common form found in these animals in South Africa and possibly also in some other parts of the world. The male is 40-70 mm. long and the female 42-60 mm., the anterior part constituting about two-thirds to three-quarters of the length. The spicule measures 4·2-4·8 mm. and its sheath bears a terminal, spherical expansion on which the spines are larger than on the remaining portion. The eggs are similar to those of *T. ovis.*

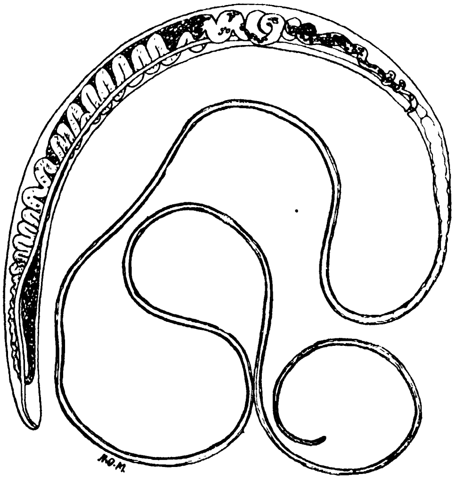

Fig. 95.—*Trichuris globulosa,* Female. (Original.)

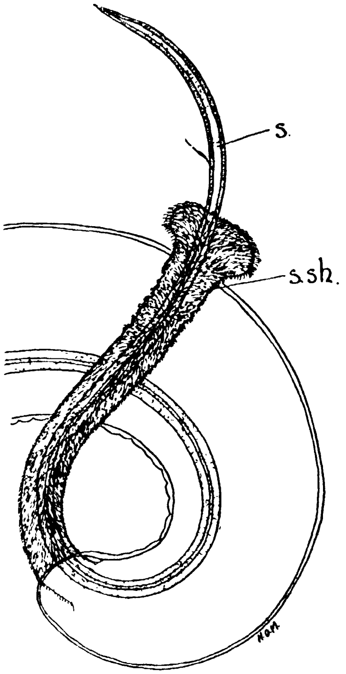

Fig. 96. — *Trichuris globulosa,* Male, Hind End. (Original.) *s.*, Spicule; *s.sh.*, spicule sheath.

T. vulpis (Fröhlich, 1789) occurs in the cæcum and other parts of the intestine of the dog and fox. The worms are 45-75 mm. long, about three-quarters of this being made up by the anterior portion. The spicule is 9-11 mm. long and the sheath bears small spines only on the proximal portion. The eggs measure 72-89 by 37-40 μ and have a brown colour.

T. trichiura (Linnæus, 1771) (syn. *T. suis*, *T. apri*, *T. dispar*, etc.) occurs in man, other primates and the pig. The male is 30-45 mm. long and the female 35-50 mm. The anterior portion forms about two-thirds of the total length. The spicule is 2-3·35 mm. long, with a blunt tip, and its sheath is variable in shape and in the extent of its spinous armature. The eggs measure 50-56 by 21-25 μ.

Life-Cycle.—The eggs reach the infective stage after about 3 weeks under favourable conditions. They may remain viable for several years. The host acquires the infection by ingesting the eggs, and the larvæ reach the cæcum, where they grow adult in about a month. In the case of *T. vulpis* Nash states that a migration through the lungs takes place.

Pathogenicity and Symptoms.—These parasites are usually not very pathogenic, but occasionally may produce an acute or chronic inflammation, especially in the cæcum of the dog and man. In human beings they have been incriminated as the cause of some cases of appendicitis. In dogs an elevated temperature and general signs of illness may be produced by heavy infections. Emmerson described a barking hysteria in dogs, associated with whipworm infection and small ulcers in the cæcum; the symptoms disappear when the worms are removed.

Diagnosis can be made by finding the characteristic eggs in the fæces, especially after a dose of arecoline.

Treatment.—Several authors (Whitney,* Emmerson,† Steinbach,‡ Corenzwit§) have described the intracæcal injection of drugs such as hydrogen peroxide, *n*-butyl chloride and nicotine with excellent results. The administration per os of *n*-butyl chloride at the rate of 1 c.c. per kilo bodyweight is about 60 per cent. effective, according to Harwood, while Guthrie obtains better results with diphenylamine in doses of 2-2·5 gm. per 10 lbs. weight. In human beings the fresh latex of *Ficus laurifolia* (" lèche de higueron "), in doses of 30 c.c. on each of 3 successive days, produces satisfactory results.

In acute cases in valuable dogs resection of the cæcum may be indicated. In the case of ruminants and pigs treatment is rarely necessary.

Prophylaxis is a matter of hygiene, aiming at the destruction of viable eggs by the action of sunlight and dry conditions. The animals should be removed from infected to suitable fresh quarters.

Genus **Capillaria** Zeder, 1800

The worms of this genus are closely related to *Trichuris*, but they are slender and the posterior part of the body is not conspicuously thicker than the anterior part. The eggs have polar plugs.

C. entomelas (Dujardin, 1845) occurs in the small intestine of the mink, beech martin and polecat, and may cause a hæmorrhagic enteritis, particularly in mink. The infection is acquired chiefly by animals kept in boxes and can be prevented only by hygienic measures. The eggs measure 56-63 by 23-27 μ.

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* *Vet. Med.*, 37 (5): 217-219. 1942.

† *Vet. Med.*, 36 (10): 522-523. 1941.

‡ *Vet. Med.*, 37 (4): 184. 1942.

§ *Journ. Amer. Vet. Med. Assn.*, 40 (6): 661-679. 1935.

C. plica (Rudolphi, 1819) occurs in the urinary bladder and sometimes the pelvis of the kidney of foxes. It is apparently relatively harmless and no treatment except sanitation is known. The eggs are passed in the urine and are colourless; they measure 63-68 by 24-27 μ.

C. hepatica (Bancroft, 1893) occurs in the liver of numerous rodents and other animals, including the rat, mouse, squirrel, muskrat, rabbit and dog. The worms are very thin and cannot easily be removed from the tissue. Their eggs are laid in the liver and can be seen in the form of irregular yellow streaks and patches on the surface and on sections. The life-cycle is apparently as follows: When an infected animal is eaten the liver is digested and the liberated eggs pass out in the fæces. Thus exposed to the air they become infective, and will then develop in a suitable animal which swallows them. This parasite is of no great practical significance. It may cause a certain degree of cirrhosis in the liver.

In birds these worms are important. The following are the most pathogenic:

C. longicollis (Rudolphi, 1819)* occurs in the small intestine of the fowl, pigeon and related wild birds. Male 9-14 mm., female 14-25 mm. long. The œsophagus is almost half as long as the body in the male and one-third as long in the female. The tail of the female is cylindrical up to the end. The vulva has a conspicuous projecting appendage. The eggs measure 53-58 by 23 μ.

C. columbæ (Rudolphi, 1819)* occurs in the small intestine of the pigeon, fowl, turkey and related wild birds. Male 9·5-11·5 mm., female 10·5-14·5 mm. long. In the male the œsophagus is more than half as long as the body; in the female it is shorter. The tail of the female tapers posteriorly. The eggs measure 48-53 by 24 μ.

C. annulata (Molin, 1858) occurs in the crop and the œsophagus of the fowl, turkey and related birds. Male 15-25 mm., female 37-80 mm. long. The cuticle of the anterior end forms a characteristic swelling. The eggs measure 60-65 by 25-28 μ.

C. contorta (Creplin, 1839) occurs in the crop and the œsophagus of the turkey, duck and many wild birds. The males are 12-17 mm. long and the females 27-38 mm. The eggs measure 48-56 by 21-24 μ.

Life-Cycle.—The eggs of most species are passed in the fæces of the host and become infective in the open after a short period. Having been swallowed by a suitable host, they hatch and the larvæ proceed with their development to the adult stage. *C. annulata*, according to Wehr, requires earthworms, *Helodrilus fœtidus* and *H. caliginosus*, as intermediate hosts. *C. longicollis* is transmitted by *H. caliginosus* according to Morehouse.

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* For detailed descriptions see Morgan, *Journ. Helm.*, 10 (4): 183-194. 1932.

Pathogenicity and Symptoms.—When present in small numbers the worms produce no lesions, but large numbers produce an inflammation varying in degree from a simple catarrh to a croupous inflammation and the formation of diphtheritic pseudo-membranes. The appetite is lost, the birds become emaciated and anæmic and many may die. In the duck *C. contorta* may cause a distension of the crop, which produces dyspnœa by pressing on the vagus nerve. This parasite may also cause inco-ordination and paralysis. *C. columbæ* is especially troublesome in pigeons where these birds are bred on a large scale for commercial purposes.

Diagnosis is usually made at autopsy by finding the parasites, but the eggs can also be found in the fæces.

Treatment.—No satisfactory treatment is known. Carbon tetrachloride is fairly effective against some intestinal capillarias.

Prophylaxis is a matter of hygiene, but presents many difficulties. The animals should be fed and watered in such a way that contamination with the eggs of the worms is eliminated as far as possible.

C. aerophila (Creplin, 1839) (syn. *Eucoleus aerophilus*) occurs in the trachea, bronchi and rarely the nasal cavities of dogs and foxes. It has also been recorded from the cat, pine marten, beech marten, wolf (*Lupus lupus*) and the badger. The male is 24·5 mm. long and the female 32 mm. There is one spicule and a spicule sheath armed with spines. The eggs measure 59-80 by 30-40 μ, including the polar plugs. They have a slight greenish tinge, and the thick shells have a " netted " surface.

Life-Cycle.—The eggs are laid in the lungs, coughed up and swallowed, and are therefore passed in the fæces. They develop in the open, reaching the infective stage after 5-7 weeks and may remain viable for over a year under favourable conditions. When they are swallowed by a suitable host, they hatch in the intestine and the larvæ migrate to the lungs in 7-10 days, reaching maturity 40 days after infection.

Pathogenesis and Symptoms.—Animals with mild infections show no symptoms and are therefore dangerous as carriers. Severe infections cause a chronic tracheitis and bronchitis. The affected animals are susceptible to secondary infections by bacteria which may cause bronchopneumonia. There is a whistling noise while the animal breathes and a deep, wheezing cough, especially at night. A nasal discharge is frequently seen. The mouth may be held open on account of dyspnœa. The animals become emaciated and anæmic, while the fur grows harsh.

Diagnosis is made by finding the eggs in the fæces or, where *Trichuris vulpis* may be present, in the sputum or nasal discharge. The possibility that eggs of *Capillaria plica* from the urine may be present must be remembered.

Treatment.—According to Hanson,* the best results are achieved by transferring the affected animals to wire-bottom pens, raised 30-40 cm. from the ground. The wire mesh should be sufficiently fine to prevent the animals from hurting their legs by falling through. A tracheal brush which removes a fair proportion of the worms from the trachea is passed about every 2 weeks until the animals are cured. The infected pens should not be used before they have been thoroughly disinfected.

Prophylaxis.—The disease occurs chiefly in young foxes up to 18 months old. The parasite is most troublesome where the soil of the pens is shaded or not properly drained. The infection is also acquired in breeding boxes, where the eggs are allowed to accumulate. Dry pens and clean boxes should therefore be the object of preventive measures. The boxes can be treated as described under ascariasis (p. 144).

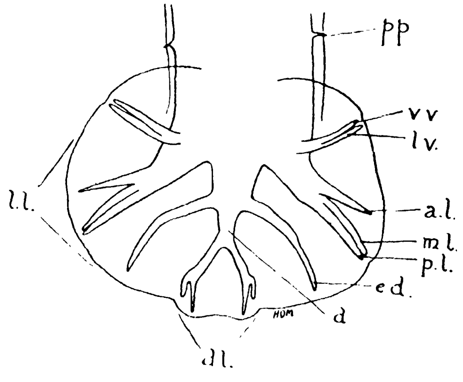

FIG. 97.—STRONGYLE BURSA, FLATTENED OUT. (ORIGINAL.)

a.l., Antero-lateral ray; *d.*, dorsal ray; *d.l.*, dorsal lobe; *e.d.*, externo-dorsal ray; *m.l.*, medio-lateral ray; *l.l.*, lateral lobe; *l.v.*, latero-ventral ray; *p.l.*, postero-lateral ray; *p.p.*, prebursal papilla; *v.v.*, ventro-ventral ray.

Order STRONGYLOIDEA

This order is characterised chiefly by the presence of a bursa at the hind end of the male. This structure consists of cuticular alæ which usually form two lateral and a dorsal lobe, enclosing the posterior extremity, and which are supported by the modified caudal papillæ, known as the "bursal rays." These rays contain muscle fibres and are arranged in a definite order. There are two ventral rays: a ventro-ventral and a latero-ventral; three lateral rays: an antero-lateral, a medio-lateral and a postero-lateral; and a set of dorsal rays usually comprising an externo-dorsal on either side of the single or divided dorsal ray. The hind end of the male enclosed in the bursa is called the "genital cone." There are usually two equal spicules, and a gubernaculum, as well as a telamon, may be present. Frequently a buccal capsule is present, and there may be small lips or leaf-crowns surrounding the oral aperture.

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* *Journ. Amer. Vet. Med. Assn.*, n.s., 35 (1): 12-33. 1933.

Family STRONGYLIDÆ

There is a well-developed buccal capsule and one or two leaf-crowns are usually present. The male bursa is strongly developed and has typical rays. The life-cycle is direct in all known cases.

Genus **Strongylus** Müller, 1780

S. equinus Müller, 1780, occurs in the cæcum and colon of equines, including the zebra. The worms are fairly rigid and dark grey in colour; sometimes the red colour of the blood in the intestine can be seen. The male is 26-35 mm. long and the female 38-47 mm. by about 2 mm. thick. The head end is not marked off from the rest of the body. The buccal capsule is oval in outline and there are external and internal leaf-crowns. At the base of the buccal capsule there is a large dorsal tooth with a bifid tip and two smaller subventral teeth. The dorsal œsophageal gland opens into the buccal capsule through a number of pores situated in a thickened ridge, the dorsal gutter, formed by the wall of the buccal capsule. The male has two simple, slender spicules. The vulva lies 12-14 mm. from the posterior extremity and the uteri are of the amphidelph type. The eggs are oval, thin-shelled, segmenting when laid, and measure 70-85 by 40-47 μ.

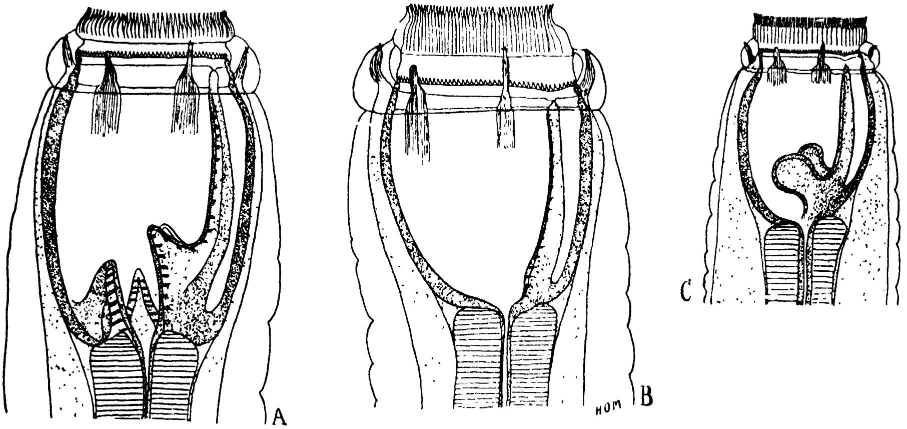

FIG. 98.—ANTERIOR END, DORSO-LATERAL VIEW, OF A, *Strongylus equinus ;* B, *S. edentatus ;* C, *S. vulgaris.* (ORIGINAL.)

Life-Cycle and Bionomics of Strongyle Larvæ.—The eggs are passed in the fæces of the host, and they, as well as the larvæ hatching from them, require oxygen, moisture and a suitable temperature for their further development to the infective stage. Eggs which lie under more than 3 mm. of water do not obtain sufficient oxygen and do not develop, but remain viable for a number of days. The eggs and larvæ in the pre-infective stage are not resistant to desiccation, but die if they become dry. Eggs of *Strongylus*, according to Looss, and also those of certain *Trichostrongylus* species, which contain fully developed embryos ready to hatch, are strongly resistant to desiccation. Such eggs are able to lie dormant under dry conditions for many months. At the optimum temperature of 26° C. the eggs hatch in about 20 hours and the infective stage is reached in 5-6 days. At lower temperatures development proceeds more slowly and it stops completely near freezing-point, but the eggs and larvæ are usually not killed even by freezing. At higher temperatures development is more rapid, but the larvæ are weak. The heat generated by fermenting manure kills the eggs and larvæ.

After hatching from the egg, the larva is in the first stage and is characterised by having a rhabditiform œsophagus. It feeds apparently mainly on bacteria and grows, but soon enters a lethargic state in preparation for the first moult, from which the second-stage larva emerges. This has a less rhabditiform œsophagus than the first-stage larva. The process of feeding and growth is repeated, followed by lethargy. The old cuticle is separated off, but is not shed, and the sheathed larva is now in the infective stage. It has a club-shaped or "strongyliform" œsophagus.

The habits of the infective larva are different from those of the younger stages. It does not feed, and has to subsist on the reserve food granules stored in its intestinal cells. As soon as these are exhausted the larva dies. Although in most cases the larva does not actively enter the host, but is swallowed with food, or sometimes water, its habits are of such a nature that they increase the possibility of finding a host. These habits can be described as the normal responses to a number of external stimuli, and the following are the most important: (i.) The larva is said to be negatively geotropic because it crawls up blades of grass or other herbage. (ii.) It is positively phototropic or heliotropic to a mild light, but is repelled by strong sunlight. The larva will therefore crawl up blades of grass only in the early morning, towards the evening and at other times of the day in dull weather. At night some of the larvæ may descend to the soil. Moisture is necessary for such migration, as the larvæ are unable to crawl on a dry surface, but a very thin film of water suffices. (iii.) There is a certain amount of response to heat; migration is more active in warm than in cold weather.

The sheath affords protection against adverse conditions, especially against dryness, so that the larvæ may now become dry and yet live for many days, the length of time depending on the temperature and the humidity of the air. Such larvæ are fairly rapidly killed by heat and direct sunlight, but not by freezing. If the conditions become unsuitable, especially on account of dryness, some larvæ penetrate into the upper layers of the soil. In loose, sandy soil they are able to move more easily and to penetrate deeper than in fine clay soil, so that from this point of view sandy soil is favourable. In water the larvæ sink to the bottom and may live for a month or more, depending on the temperature and the presence of other organisms which appear to affect them.

Taking all these factors together, the length of life of a larva in a pasture is favourably affected by moisture, shade and a relatively low temperature. Since the larvæ do not feed and there is a limited amount of available energy, conditions favourable for migration, like warmth, marked daily fluctuations in the intensity of light and loose soil, lead to rapid exhaustion and death. In general, under such conditions, as well as during dry seasons, the larvæ will not live longer than about 3 months, but they may live for a year or longer in a cool climate where sufficient moisture is available in the soil. Under certain conditions, especially after having been dry, the sheath is lost and the larvæ are then much less resistant.

After the larvæ have been ingested by a suitable host they cast off their sheaths and, in the case of *S. equinus*, penetrate into the mucosa of the intestine. According to Wetzel* they pass to the submucosa or muscularis, where they become enclosed in nodules. After about 11 days fourth-stage larvæ emerge and migrate to the liver, via the peritoneal cavity, where they stay some 6-7 weeks. The rest of the life-cycle is not clear. Some young worms reach the pancreas. The fourth ecdysis occurs about the 118th day, but the migratory period is prolonged and even after 5 months the worms had not returned to the intestine. Migration through the lungs does not occur.

S. edentatus (Looss, 1900) also occurs in the large intestine of equines. The male is 23-28 mm. long and the female 33-44 mm. by about 2 mm. broad. This worm resembles *S. equinus* macroscopically, but the head is somewhat wider than the following portion of the body. The buccal capsule is wider anteriorly than at the middle and contains no teeth.

Life-Cycle.—Similar to that of *S. equinus*. After ingestion by the host the larvæ penetrate through the wall of the intestine, especially the cæcum and colon, and reach the connective tissue underlying the peritoneal lining of the abdominal cavity, where they form hæmorrhagic nodules. Here they remain for about 3 months and increase considerably in size. At the end of this stage of their development the larvæ migrate towards the root of the mesentery and, moving along between the two layers of this organ, reach the wall of the intestine into which they penetrate. In this way the young worms become lodged in large hæmorrhagic nodules which eventually open into the lumen of the intestine and release the worms, which then grow adult. Erratic forms are frequently seen in various organs like the lungs and liver; several adult specimens have been found in a hæmatoma of the abdominal wall.

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* *Arch. wiss. prakt. Tierheilk.*, 76 (2): 81-118. 1940.

S. vulgaris (Looss, 1900) occurs in the large intestine of equines. The male is 14-16 mm. long and the female 20-24 mm. by about 1·4 mm. thick. This worm is distinctly smaller than the two preceding species. The buccal capsule is roughly oval and contains two ear-shaped dorsal teeth at its base. The elements of the external leaf-crown are fringed at their distal extremities.

Life-Cycle.—The free stages develop like those of *S. equinus*. After having entered the host the larvæ penetrate into the wall of the intestine and migrate through the body. Some are almost invariably found in the wall of the cranial mesenteric artery, where they give rise to the formation of an aneurysm and the deposition of a thrombus on the altered intima of the vessel. The normal route of migration through the body is not definitely known. Much has been written on this subject, and it may be said that there are two schools of thought. Some believe that development in the aneurysm is the normal course and that the larvæ are later transported back to the intestinal wall by the blood, after they have escaped from the aneurysm into the lumen of the artery. Then they work their way through the wall like the returning larvæ of *S. edentatus* Others agree that some larvæ develop in this way, but maintain that they have gone astray and that the normal route of migration is a different one. It is pointed out that the number of larvæ which develop in aneurysms are not sufficient to produce the number of worms found in the intestine in severe cases. A migration through the lungs does probably not occur.

The following *Strongylidæ* also occur in the large intestine of equines and are known as the "small strongyles":

Four species of *Triodontophorus* which are up to 25 mm. long and have subglobular buccal capsules with three pairs of teeth at the base. According to Ortlepp, development of the parasitic stages takes place in the lumen of the intestine without migration. *T. tenuicollis* produces ulcers in which bunches of the worms may be found attached in the right dorsal colon.

Œsophagodontus robustus and two species of *Craterostomum*, all with subglobular buccal capsules, the former also provided with teeth.

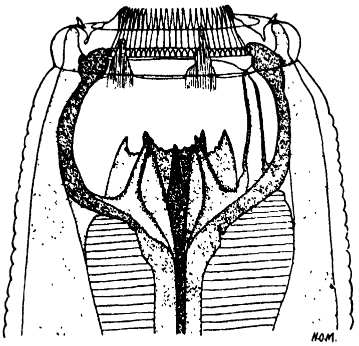

FIG. 99.—*Triodontophorus serratus*, ANTERIOR END, DORSO-LATERAL VIEW. (ORIGINAL.)

Gyalocephalus capitatus, two species of *Poteriostomum* and about thirty-five species of *Trichonema* (syn. *Cylicostomum*), which all have relatively short, cylindrical buccal capsules and a short dorsal gutter. Some of the *Trichonema* larvæ pass the first part of their parasitic existence in nodules of the intestinal wall.

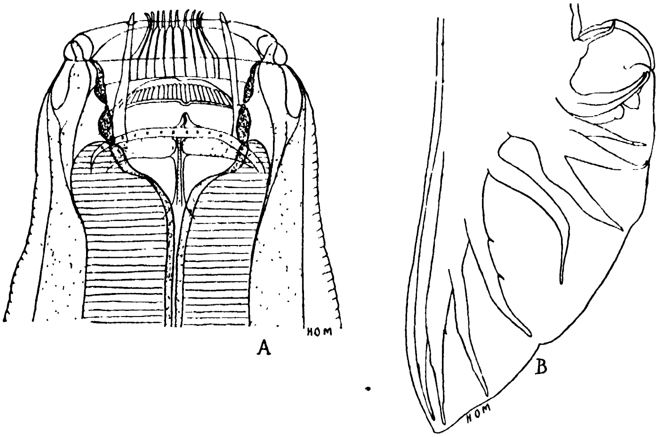

FIG. 100.—*Trichonema tetracanthum*. (ORIGINAL.)
A, Anterior end, dorsal view; B, hind end of male, lateral view.

EQUINE STRONGYLIDOSIS

Some of the equine strongyles are blood-suckers and others are not, but since the infection is usually a mixed one, the general symptoms can be considered to be caused by all the worms collectively. The blood-sucking species are the most harmful.

Pathogenesis and Symptoms.—The worms attach themselves to the mucosa by drawing it into the buccal capsule in the form of a plug. The secretions of the œsophageal glands now act on the mucosa, digesting and liquefying the cells, and the products are then ingested by the worm. Most of the *Trichonema* species attack only the superficial layers of the mucosa and draw little or no blood. Other strongyles, especially because they have large buccal capsules, draw in deeper portions of the mucosa* and rupture the bloodvessels after having digested the superficial layers, or cut into the mucosa by means of their teeth and suck blood. The parasites consequently irritate the mucosa and cause loss of blood to the host. The young worms of some species further affect the intestine by producing nodules in its wall during a part of their life-cycle. Whether the worms produce toxic secretions or excretions is not known, but it is probable that they will be harmful when they die and disintegrate in the bowel.

Especially young equines suffer from the infection. The fæces become soft and have a bad odour. Later diarrhœa develops, the appetite diminishes, the animals become emaciated, easily exhausted and the coat is rough. Anæmia develops and may become marked and associated with œdematous swellings on the abdomen and the legs. Various degrees of the disease are seen, depending on the number of the parasites present and the condition and food of the animal. Death may occur in severe cases.

S. vulgaris is believed by many authors to be the cause of numerous cases of colic on account of the aneurysms it produces. That this may be the case is shown by the reduction of cases of colic following on measures taken to prevent infection by this parasite. Again, opinions differ with regard to the rôle played by the aneurysm and its associated thrombus in the production of colic. According to many writers, portions of the thrombus may break away and cause embolism of an artery which supplies a portion of the intestine, thus producing a local anæmia and reduced peristalsis, followed by stagnation of the contents and intussusception or volvulus. Olt and others point out that (as a consideration of the vascular supply of the cæcum and colon will show) either a very large artery or at least two smaller arteries would have to become blocked simultaneously to produce such a condition. It is maintained by Olt and supported by the pathological studies of Möllmann,* that the inflammatory process produced by the larvæ in the wall of the cranial mesenteric artery affects the nerves of the cœliac and anterior mesenteric plexuses, which lie in or close to the adventitia of the vessel, and even extends to the ganglia themselves. The affected nerve supply of the intestine creates suitable conditions for the occurrence of impaction, volvulus and intussusception, and the aneurysm is therefore only indirectly responsible for the production of these cases of colic.

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* Wetzel, *Miessner Festschrift.* M. and H. Schaper, Hanover, 1930.

In other cases the thrombus grows out of the cranial mesenteric artery into the aorta and may then break off, becoming lodged in the iliac artery and causing intermittent lameness.

The hæmorrhagic nodules, formed by the young stages of *S. edentatus* under the peritoneal lining of the abdominal wall, may rupture and lead to sudden death through internal hæmorrhage.

Post-Mortem.—There may be anæmia and emaciation, even ascites, œdemas and cachexia. Erratic forms of the parasites may be found in various organs.

In the intestine the worms are found free or attached to the mucosa, which shows numerous small red bite marks or ulcers caused by *Triodontophorus tenuicollis.* The wall of the organ may contain nodules of various sizes, the large, hæmorrhagic ones being those caused by the larvæ of the large strongyles returning after migration, while the small ones are produced by the larvæ of some other species which develop in the intestinal wall.

Diagnosis.—The eggs of the *Strongylus* species can be differentiated from those of the other equine strongyles (see egg plate). As a rule it is only necessary to make a diagnosis of strongylidosis by finding the oval, thin-shelled eggs. The presence of an aneurysm in the cranial mesenteric artery could be determined in small horses by rectal palpation.

Treatment.—The drug of choice against all equine strongyles is phenothiazine, which is discussed below. Formerly other drugs were used and the following particulars refer to them: In order to reduce the contents of the large intestine the animal should be starved for 36 hours before treatment if possible. Carbon tetrachloride in a dose of 10 c.c. per 100 kilos (50 c.c. per 1,000 lbs. or more) is very effective against the blood-sucking strongyles and kills a fair proportion of the others, while oil of chenopodium at the rate of 3·5 c.c. per 100 kilos (4 drams per 1,000 lbs. or more) is fairly effective against both, especially the non-blood-sucking species. Carbon tetrachloride (see p. 50) is administered through a stomach tube, which must be passed well into the stomach, otherwise the drug is liable to cause a spasm of the cardia, followed by regurgitation and inhalation of the fluid with fatal result. Chenopodium oil can be administered in the same way or in the form of a drench, mixed with a litre of liquid paraffin. Both these drugs should be given in smaller doses to highly bred horses; chenopodium oil may produce laminitis in such animals. It is especially contra-indicated in constipation, gastro-enteritis, febrile conditions and pregnancy. N-butylidene chloride, 0·2 c.c. per kilo (about 90 c.c. per 1,000 lbs.), followed in 5 hours by a quart of raw linseed oil, is also effective against strongyles. Since a large number of larvæ may be migrating through the body, treatment should be repeated after 3 to 6 months, when they have returned to the intestine.

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* *Ztschr. f. Vet.-kde.*, 44 (8): 273-288. 1932.

Prophylaxis.—Moist pastures as well as over-stocking should be avoided. If possible, pasture rotation should be practised. The foals require special attention and are best kept away from the older horses on a clean pasture. Regular treatment will do much to decrease the infection. The stable should be cleaned frequently and kept dry. Water and food should be supplied in such a way that contamination is avoided. The much-practised method of piling up the bedding underneath the manger during the daytime assists the larvæ to migrate into the manger and contaminate the food, particularly in a dark, moist stable. Proper manure disposal will do much to reduce the infection by killing off the eggs and larvæ through the heat produced during fermentation (see p. 319).

Phenothiazine or thio-diphenylamine is an anthelmintic of great value. It is a pale yellow powder which darkens on exposure to light. Commercial samples are usually slaty-grey. It is very slightly soluble in water (1 : 800,000) and is not readily suspended in water unless a wetting agent is added. It is administered to animals in the form of (1) an aqueous suspension as a drench; (2) pills, tablets, capsules or boluses; or (3) a powder mixed in the food. In the latter case mass treatment is sometimes carried out, but this is risky, as some individuals may get an over-dose.

Large doses are required and the reason for this is not clear, especially because much of the dose is often passed unaltered in the fæces. It may be that successive small quantities which become dissolved in the digestive tract, and so able to act on the worms, are also rapidly eliminated through absorption, so that further quantities must be available. The rate of passage of the drug past the site of the worms is important: the effective dose for a horse is the same as for a sheep, viz. 25 gm. The rate of passage through the abomasum, small and large intestines of the sheep is rapid in comparison to the rate through the colon and cæcum of the horse. The drug is very effective against the strongyles in the large intestine of the horse, but erratic in its action on ascarids in the small intestine. In the horse 5 daily doses of 5 gm. or even 25 daily doses of 1 gm. are as effective as one dose of 25 gm., again probably on account of the prolonged action in the colon. But this prolonged stay also promotes absorption in the same way that constipation would act; and it is known that constipation makes the use of phenothiazine dangerous, while the horse is the most susceptible to phenothiazine poisoning among the domestic animals.

In the blood the drug is transformed into colourless, leuco- or hydroxy compounds which are excreted mainly in the urine, and also in the milk, and turn red on exposure to the air, forming the fast dyes thionol and phenothiazone. If the drug is wetted it also oxidises to form these red dyes, and staining of wool or white hairs can therefore readily occur as a result of spilling during drenching or through the urine.

In interpreting the results of treatment it must be noted that the drug inhibits egg production of worms for several days and re-examination should be done only about 14 days after treatment.

The doses and approximate percentage efficacy of the drug for the different animals and worms are as follows:

1. *Horse.*—The dose for an adult is 25-30 gm. per 1,000 lbs. live weight, given as a bolus or in a bran mash in one dose or, preferably, in several daily doses of 5 gm. each. The percentage efficacy against various parasites is approximately: strongyles 100, *Ascaris* 0-100, *Oxyuris* 25, *Trichostrongylus axei* 50, *Habronema* 0, tapeworms 0, *Strongyloides* 0, worms in aneurysms 0, bots 0.

2. *Sheep and Goats.*—Dose 0·4-0·5 gm. per lb. live weight, or 20-50 gm. for an adult. Administered as pills or a drench. After bluestone stimulation of the œsophageal groove reflex, the dose can be reduced by one-half if given as a drench, but the quantity is large and tedious to administer by drenching, apart from the danger of staining the wool. Pills can be administered rapidly by means of suitable tongs. Efficacy: *Hæmonchus* 100, *Ostertagia* 80-100, *Trichostrongylus axei* 80-100, *Trichostrongylus* spp. in small intestine 40-80, *Bunostomum* 60-100, *Nematodirus* 0-50, *Œsophagostomum* 75-100, *Chabertia* 75-100, *Strongyloides* 0, *Moniezia* 0, *Trichuris* 0, *Fasciola* 0, lungworms 0.

Small daily doses of 0·5 gm. per sheep prevent the development of worm eggs passed in the fæces (not lungworms) and so stop pasture infection. Salt licks containing about 10 per cent. of the drug are effective if given over a long period, but are expensive and may lead to serious discoloration of the wool.

3. *Cattle.*—Dose 0·2 gm. per lb. live weight, or about 30 gm. for a full-grown animal. Administered as drench or pills. Efficacy: *Hæmonchus* 80-100, *Ostertagia* 80, *Trichostrongylus axei* 80-100, *Cooperia* 50, *Bunostomum* 50-100, *Moniezia* 0, *Œsophagostomum* 75-100.

4. *Pigs.*—Dose 0·2-0·25 gm. per lb., or up to 25 lbs. 5 gm., 25-50 lbs. 8 gm., 50-100 lbs. 12 gm., 100-200 lbs. 20 gm., over 200 lbs. 30 gm. Given in food, as drench or pills. Efficacy: stomach worms 0, *Ascaris* (adults) 50, *Œsophagostomum* 80-100, *Trichuris* 0, *Macracanthorhynchus* 0.

5. *Dogs.*—Ineffective.

6. *Fowls.*—Dose 0·5 gm. per bird, given as a pill. Efficacy: *Ascaridia* 50, *Capillaris* 0-50, *Heterakis* 90-100, *Cheilospirura hamulosa* 0, tapeworms 0.

Preparatory Treatment.—No starvation is necessary and in horses it is contra-indicated. Some authors recommend a fast of 18-24 hours for cattle. Constipation should be relieved before treatment, especially in horses.

Toxicity.—Overdosing must be avoided, particularly in horses. Thoroughbreds appear to be more susceptible than other types. In general there is a tendency to develop anæmia, which reaches its maximum 2-3 weeks after treatment and may last a few weeks longer. This is most pronounced in horses and man and is not important in other animals with ordinary doses. Quick relief is obtained by transfusion. In goats a temporary reduction in the milk yield was noted. The drug is apparently safe in pregnancy. Very young animals are distinctly more susceptible to poisoning than older animals and are better treated with other drugs where such are available.

Symptoms of Poisoning.—In horses there is a rise of temperature, anorexia, weakness, dullness, in some cases colicky pains and staggering, frequently icterus, constipation with mucus-covered fæces, dyspnœa, weak pulse, sometimes albuminuria and hæmoglobinuria, progressive anæmia. In cattle similar symptoms have been noted. In pigs inco-ordination and paralysis, especially of the hind-quarters—but they feed and drink when held up to the trough—vomition, rectal prolapse and a transitory corneal opacity are the usual symptoms. Photosensitisation and dermatitis have also been noted.

Post-Mortem after Poisoning.—Horses show gastritis with erosions, slight enteritis, enlarged and congested liver, spleen and kidneys, ureteritis, and an enlarged heart with subendocardial hæmorrhages. Cattle show œdema and ulceration of the abomasum, enteritis and congested liver and kidneys. Pigs show lesions of the digestive tract, liver and kidneys as above.

Contra-indications.—Extreme anæmia (especially in horses), emaciation, severe constipation, diseases of the heart, kidney and liver. Very young animals should not be treated, foals not under 9 months. It seems as if molasses in the food of horses during treatment is dangerous. The drug is usually considered to be safe in pregnancy, but abortion has been reported after treatment of highly pregnant ewes.

Genus **Codiostomum** Railliet and Henry, 1911

C. struthionis Horst, 1885, occurs in the large intestine of the ostrich. The male is about 13 mm. long and the female 17 mm. The buccal capsule is subglobular, provided with external and internal leaf-crowns, but there are no teeth. The male bursa has a large projecting dorsal lobe and the vulva of the female is situated close to the anus.

Life-Cycle.—Unknown; probably direct.

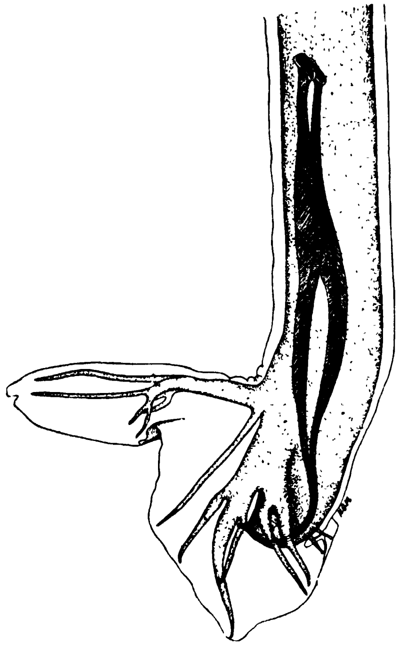

FIG. 101.—*Codiostomum struthionis*, HIND END OF MALE, LATERAL VIEW. (ORIGINAL.)

Pathogenicity and Symptoms.—Little is known, but the parasite must be considered as dangerous, especially in heavy infections.

Treatment.—Carbon tetrachloride should produce satisfactory results and can be administered in capsules or mixed with oil, as in the case of poultry.

Prophylaxis.—Since the life-cycle is probably direct, regular treatment and the supply of clean food and water are important. The runs should be frequently cleaned of fæces and the chicks raised apart from the adult birds.

Genus **Bourgelatia** Railliet, Henry and Bauche, 1919

B. diducta Railliet, Henry and Bauche, 1919, occurs in the cæcum and colon of the pig in India, Indo-China and Java. The male is about 10 mm. long and the female about 12 mm. The buccal capsule is cup-shaped. The external leaf-crown has 21 long elements projecting from the oral aperture and the internal leaf-crown has an equal number of elements. The spicules are equal, alate, 1·12-1·24 mm. long. The vulva opens near the anus. The eggs measure 58-60 by 36-38 μ.

Life-Cycle.—Probably direct.

Pathogenicity.—Very little is known about the effects of this parasite on its host.

Genus **Œsophagostomum** Molin, 1861

Œ. columbianum (Curtice, 1890), the "nodular worm," occurs in the colon of the sheep, goat and a number of wild antelopes. It has once been recorded from cattle, probably due to a faulty determination. The male is 12-16·5 mm. long and the female 15-21·5 mm. by about 0·45 mm. wide. There are large cervical alæ which produce a marked dorsal curvature of the anterior part of the body. The cuticle forms a mouth-collar which is fairly high, shaped like a truncate cone and separated from the rest of the body by a constriction. About 0·25 mm. from the anterior end there is a cervical groove which extends around the ventral surface to the lateral aspects of the body. The cuticle anterior to this groove is slightly inflated to form a cephalic vesicle. Immediately behind the cervical groove the cervical alæ arise and their anterior extremities are pierced by the cervical papillæ. The buccal capsule is shallow and wider anteriorly than posteriorly. The external leaf-crown consists of 20-24 elements and the internal has two small elements to each of the external. The male bursa is well developed and there are two equal, alate spicules, 0·77-0·86 mm. long. The tail of the female tapers to a fine point. The vulva is situated about 0·8 mm. anterior to the anus. The vagina is very short, transverse, leading into the kidney-shaped "pars ejectrix" of the ovejectors. The eggs have thin shells and are laid in the 8- to 16-cell stage. They measure 73-89 by 34-45 μ.

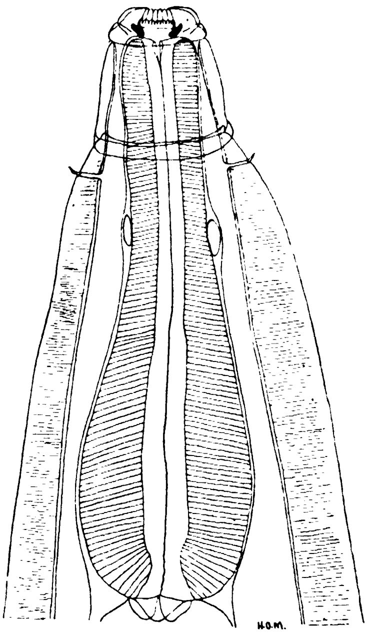

FIG. 102.—*Œsophagostomum columbianum*, ANTERIOR END, DORSAL VIEW. (ORIGINAL.)

Life-Cycle.—The eggs are passed in the fæces of the host and the development and bionomics of the free stages are as described under *Strongylus equinus* (p. 164). The infective stage is reached under optimum conditions in 6-7 days. None of the pre-infective stages are resistant to desiccation. After having been ingested by the host the larvæ cast their sheaths and penetrate into the wall of the intestine, anywhere from the pylorus to the rectum. Here the third ecdysis takes place and the larvæ grow to a length of about 1·5-2·5 mm. They now have a subglobular buccal capsule with a dorsal tooth at the base, and the cervical groove is conspicuous. Normally they return to the lumen of the gut after 5 days and pass to the colon, where they grow adult after the fourth ecdysis. The first eggs are passed in the fæces of the host 41 days after infection.

Pathogenesis.—In lambs, or in older sheep that have no resistance against the parasite, the larvæ incite practically no reaction by their migration into the mucosa, so that eventually a large number of adult worms can be found in the colon while there are no nodules in the wall of the intestine. In other cases, when the mucosa itself appears to possess some degree of immunity, the larvæ pass into the submucosa and a marked reaction takes place in the form of a localised inflammation around each larva. Leucocytes, especially eosinophiles, and foreign body giant cells collect around the parasite and the focus becomes encapsulated by fibroblasts. The larvæ may stay in these nodules for about 3 months, and when the contents caseate and calcify the parasite either dies or leaves the nodule and then frequently wanders about between the muscle fibres, leaving behind it a narrow canal filled with material similar to that found in the nodules. Although the nodules usually have a small opening through which pus is discharged into the intestine, the large majority of these larvæ do not find their way back into the lumen. In such cases the intestinal wall may therefore show numerous nodules and tracks, while the colon contains few or no adult worms.

The presence of nodules in the intestinal wall is of no importance unless they occur in large numbers, when they may cause such a marked rigidity that peristalsis is interfered with and the processes of digestion and absorption are probably greatly reduced. During the regressive stage the nodules possibly form centres of intoxication for the body. A group of nodules surrounding the intestine at one point, or circular tracks, may cause stenosis, but such cases are rare. Some larvæ may enter the blood or lymph vessels or pass into the abdominal cavity and produce nodules in other organs, especially the liver, lungs, myocardium and abdominal fat. Although most nodules are sterile, the larvæ may carry bacteria into the intestinal wall and an acute inflammation results, frequently followed by peritonitis when the resulting abscess opens into the peritoneal cavity. Intussusception apparently very rarely occurs as a result of the presence of nodules, although this has in the past frequently been thought to happen.

The young worms, returning into the lumen of the intestine, cause an intense irritation of the mucosa, resulting in diarrhœa. The adult worms are not blood-suckers and do not attach themselves to the mucosa, but, according to Wetzel, they irritate the mucosa, probably by means of secretions of their œsophageal or cephalic glands, and the resulting mucous inflammatory products serve as their food. The worms undoubtedly secrete a substance which is absorbed by the host and has a toxic action on the body. If the worms are removed, even extreme cases recover rapidly, although there may be many nodules.

Symptoms.—In lambs the first symptom is a marked and persistent diarrhœa, which results in exhaustion and death unless the animals are removed from the infected pasture. The fæces usually have a dark green colour. This diarrhœa begins on the sixth day after a severe infection and coincides with the time when the larvæ leave the nodules. In more chronic cases there may be an initial diarrhœa, later followed by constipation and occasional spells of diarrhœa. The animal shows progressive emaciation and general weakness. Anæmia is slight unless other worms are also present. The skin becomes dry and the wool is unthrifty, but is usually not as loose as in sheep suffering from blood-sucking worms. The characteristic picture of chronic œsophagostomiasis in sheep is that of extreme emaciation and cachexia with atrophy of the muscles, ending in complete prostration for 1-3 days and death.

The symptoms of complications are those of intestinal stenosis and peritonitis.

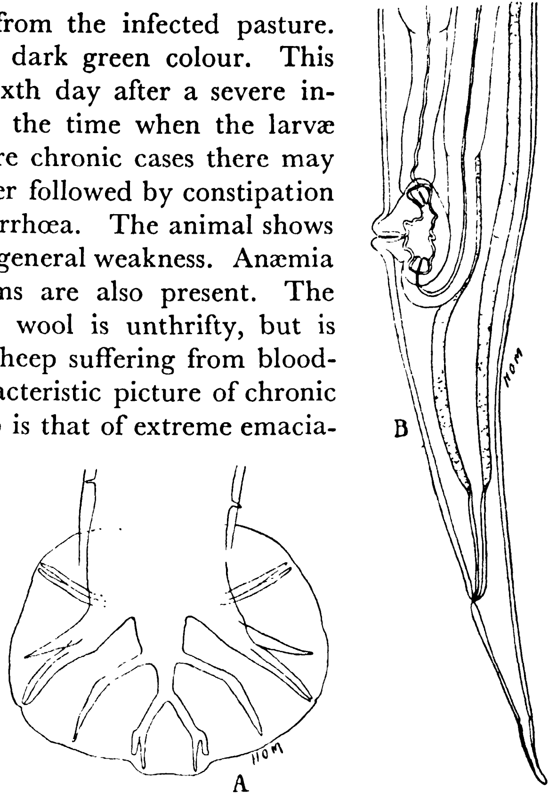

FIG. 103.—*Œsophagostomum columbianum.* (ORIGINAL.)

A, Bursa of male; B, hind end of female, lateral view.

Post-Mortem.—In acute cases the wool around the anus is soiled with diarrhœic fæces. There may be a mild enteritis, but this is not usually seen. The young worms may be found in scrapings of the mucosa, especially in the anterior part of the colon. In chronic cases the animals are emaciated, there is practically no fat in the body, the body cavities contain a clear fluid, and there may be a slight anæmia. Nodules are present in the intestinal wall, measuring 2-10 mm. or more in diameter and containing a light green, pasty material. Older nodules have a greyish-brown, crumbly content, or they may be calcified. Frequently the larvæ can be found in the nodules. The adult parasites are found in the anterior part of the colon, lying between the fæces and the mucosa, usually in a thick, transparent mucus. Most of the parasites are concentrated at the junction of the wide and the narrow part of the colon, and here the mucosa may be thickened, reddish and partly desquamated. In some cases, especially when the sheep have been subjected to repeated infections, the intestinal wall may be much thickened and rigid on account of the numerous nodules in it, while no adult worms are present. Such cases probably die as a result of interference with metabolism, produced by the nodules mechanically or possibly by a toxin absorbed from the nodules. The thyroid glands are normal macro- and microscopically.

When death is due to peritonitis the abdomen contains a dirty yellow fluid and the organs are covered with a light brown fibrinous mass. The wall of the intestine contains nodules, some of which are situated in the centres of bright red areas on the peritoneal surface.

Diagnosis.—Examination of the fæces will show the fourth-stage larvæ in acute cases with diarrhœa or the presence of eggs in other cases. Chronic cases without adult parasites can be diagnosed only tentatively if the symptoms are considered together with the anamnesis. Since the eggs of *Œ. columbianum* cannot easily be differentiated from those of many other gastrointestinal nematodes of sheep, fæcal cultures have to be made and examined when the larvæ have reached the infective stage. The infective larvæ of *Œ. columbianum* and other species of this genus have a sheath provided with a long, whip-like tail, while the tail of the larva itself is much shorter and ends in a simple point. The sheath is rather loose and shows characteristic transverse wrinkles, which are not so marked in the case of other larvæ. The table on p. 181 gives the approximate measurements in millimetres of some of the most important infective larvæ found in sheep fæces cultures.

Treatment.—Phenothiazine (see p. 171) is highly effective. However, the drug is expensive and cannot be administered regularly every few weeks. Its administration at certain selected times of the year is therefore necessary and leads to very effective control under certain climatic conditions. The best time for treatment is towards the end of a period during which the following conditions have been fulfilled: (1) the larvæ in the pasture have been practically exterminated, either by extreme cold as in Canada and similar countries, or by prolonged dryness as in other countries during certain seasons; (2) re-infection of sheep has not occurred for some time, as a result of being stabled or of running on very dry pastures, and therefore there will be few larvæ left in nodules where they are not accessible to drugs; and (3) as a consequence of these factors the source of future infection will be in the sheep alone and accessible to treatment. A good dose at such a time (Swales in Canada recommends 50 gm. for an adult sheep) will do much to control infection for the rest of the year.

Owing to the location of the adult parasites in the colon, treatment with other drugs is difficult. The discoveries of Ross* in Australia and Mönnig and Quin† in South Africa, that 2·5 c.c. of a 10 per cent. solution of copper sulphate, when given to sheep per os, stimulates the vagus nerve in the pharynx, causing reflex closure of the œsophageal groove, have made it possible to administer drugs in the form of liquids, powders or small pills so that they will be swallowed directly into the abomasum. The drug must be given within about 15 seconds after the stimulant, as long as the reflex lasts, and is best given immediately after the stimulant. Fluid ruminal contents favour the occurrence of the reflex and the rapid passage of drugs through the intestine, and it is therefore desirable to allow the animals to drink water immediately before treatment. Since the abomasal mucosa is tender, care must be exercised in the administration of drugs by this method.

The drug, having arrived in the abomasum in a concentrated form, can now pass in bulk down the intestine and may reach the colon still sufficiently concentrated to be effective against parasites situated there. Absorption from the intestine is the remaining difficulty, and this is much complicated by the great variation in stomach acidity, which may vary from almost neutral to about 0·3 per cent. HCl equivalent under different conditions, and which affects the solubility and consequently the absorbability of many drugs.

In South Africa Mönnig‡ has developed a nodular worm remedy which consists of 1 part (weight) copper arsenate, 2 parts copper tartrate and 2 parts calcium hydroxide, the doses being for sheep 3-7 weeks old 0·25 gm., 8-12 weeks 0·5 gm., over 3-6 months 1 gm., over 6-18 months 1·8 gm., over 18 months 2·5 gm. The animals should be dosed on a full stomach and should receive no grain ration or salt for 2 days beforehand. Suckling lambs should have no milk for 4 hours before until 4 hours after treatment. The treatment is more effective on green than on dry pasture, as the quality of the food affects the rapidity of passage through the small intestine. The animals should be handled as quietly as possible, since excitement apparently affects the fate of the remedy adversely. The dose may be repeated after 24 hours and such double doses may be given every 6 weeks, but better results have been obtained against *O. columbianum* and *H. contortus* by single doses repeated every 3 weeks over a period of several months. The remedy is not completely effective, but continued regular treatments can clean a flock and prevent further infection of the pasture.

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* *Austral. Vet. Journ.*, February, 1934: 11-25.

† *Ond. J. Vet. Sc. Anim. Ind.*, 5 (2): 485-499. 1935.

‡ *Ibid.*, 5 (2): 419-438. 1935.

Prophylaxis against Nematode Parasites of Ruminants.—Experience has shown that the following measures are of the utmost importance in the control of all nematode parasites, including lungworms, of ruminants:

(i.) The animals should be well fed and supplied with licks containing those minerals in which the pasture is deficient. Well-nourished sheep are much less susceptible to infection than others, and even if some worms do establish themselves, their effects are hardly noticed and a spontaneous cure soon occurs. If, however, the pasture is heavily infected, the worm burden may be too severe even for well-fed sheep.

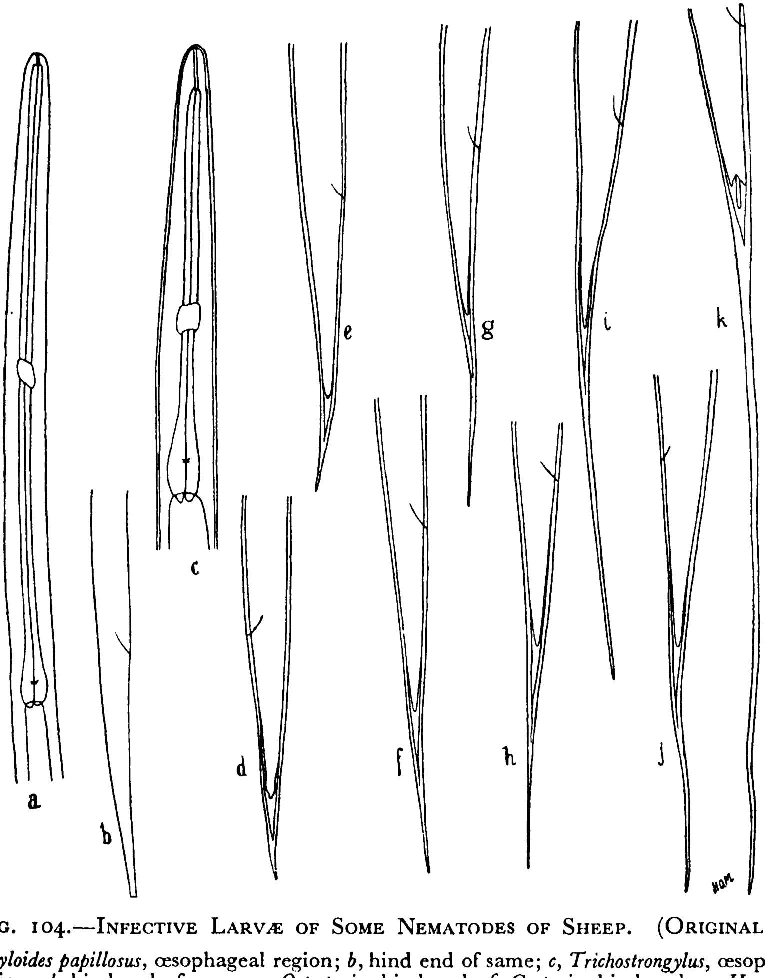

FIG. 104.—INFECTIVE LARVÆ OF SOME NEMATODES OF SHEEP. (ORIGINAL.)

a, Strongyloides papillosus, œsophageal region; *b*, hind end of same; *c*, *Trichostrongylus*, œsophageal region; *d*, hind end of same; *e*, *Ostertagia*, hind end; *f*, *Cooperia*, hind end; *g*, *Hæmonchus*, hind end; *h*, *Bunostomum*, hind end; *i*, *Œsophagostomum*. hind end; *j*, *Chabertia*, hind end; *k*, *Nematodirus*, hind end. (All drawn to same scale.)

(ii.) The animals should be regularly treated in order to keep them free of the most harmful worms, like *Hæmonchus contortus*, so that they will be able to overcome the other parasites themselves. The importance of this measure has been abundantly proved where it has been applied. If a dry season occurs, the sheep should be cleansed of all worms as far as possible during this period, while the pasture is being sterilised by the climatic conditions.

(iii.) Overstocking tends to concentrate worm infection and should therefore be avoided. On the other hand, pasture rotation allows the animals to graze on clean pastures at intervals while the infected paddocks can be left to become clean.

(iv.) Since calves, lambs and young sheep are the most susceptible to worms, they should be separated from their mothers as early as possible and graze in a clean paddock. In countries where a dry season occurs the beginning of this period is the best lambing time if provision for green fodder can be made. The lambs arrive at a fairly safe period, while the dry conditions also assist in cleansing a paddock into which the lambs can be put after weaning.

(v.) Wet or moist pastures as well as other wet places like the edges of pools of water or dams, which present very suitable conditions for the development and maintenance of worm larvæ, should be avoided. The animals are best watered from troughs surrounded by gravelled areas, in order to prevent moisture from accumulating. If the water of a dam has to be used, it should be fenced in and the water led to a trough through pipes which do not catch the mud at the bottom of the dam. If possible, the animals should be allowed to graze only when there is no dew on the grass.

(vi.) Stabled animals should be fed from raised troughs and hay-racks, and great care must be taken that the food is not contaminated by bedding or fæces and that infective larvæ do not migrate into it from the floor.

	Total Length.	*Œsophagus.*	*Tail of Larva.*	*Tail of Sheath.*
Strongyloides papillosus (filariform larva) ..	0·6	0·23	0·09	Sheath absent.
Trichostrongylus instabilis	0·69	0·165	0·06	0·094
Ostertagia spp.	0·84	0·16	0·075	0·112
Cooperia spp.	0·78	0·16	0·067	0·124
Hæmonchus contortus	0·69	0·136	0·06	0·142
Bunostomum trigonocephalum	0·57	0·16	0·06	0·140
Chabertia ovina	0·73	0·165	0·064	0·165
Œsophagostomum columbianum	0·79	0·16	0·07	0·214
Nematodirus spathiger	1·1	0·225	0·056	0·326

Œ. venulosum (Rudolphi, 1809) occurs in the colon of sheep, goat, deer and camel. There are no lateral cervical alæ and the worms are therefore not curved anteriorly. The cervical papillæ are situated behind the level of the œsophagus. The external leaf-crown consists of 18 elements. The vagina of the female is 0·5-0·6 mm. long and the spicules of the male 1·1-1·2 mm.

Œ. asperum Railliet and Henry, 1913, occurs in the colon of the goat. It resembles the previous species, but the external leaf-crown has only 12 elements and the vagina measures 0·66-0·7 mm., while the spicules are 1·5-1·7 mm. long.

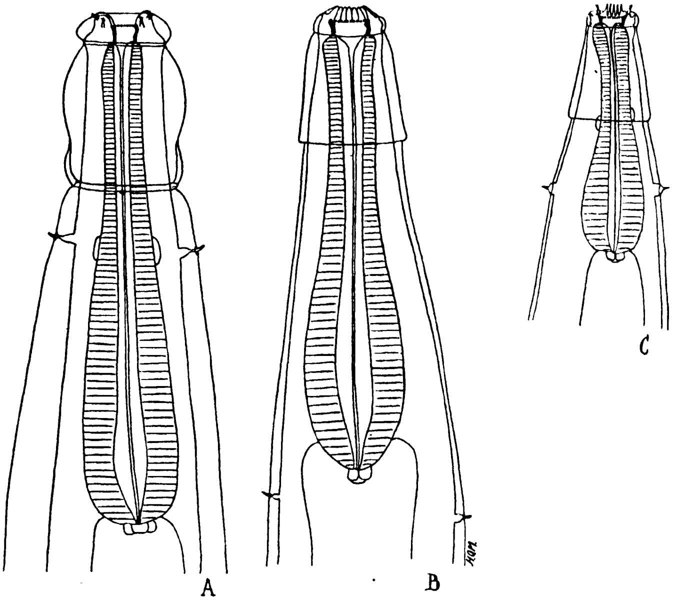

Fig. 105.—Anterior End, Dorsal View, of A, *Œsophagostomum radiatum;* B, *O. venulosum;* C, *O. dentatum.* (Original.)

Œ. radiatum (Rudolphi, 1803) occurs in the colon of cattle. It is characterised by a rounded mouth-collar, a large cephalic vesicle which is constricted behind its middle and the absence of an external leaf-crown. The internal leaf-crown consists of 38-40 minute elements. The vagina is short as in Œ. *columbianum.*

Œ. dentatum (Rudolphi, 1803) and several other species of this genus occur in the colon of the pig. In this species the males are 8-10 mm. long and the females are 11-14 mm. The cephalic vesicle is prominent, but cervical alæ are practically absent. The submedian head papillæ project forward conspicuously, as well as the nine elements of the external leaf-crown.

The life-cycle of these worms is similar to that of Œ. *columbianum*, but only *Œ. radiatum* and some or all of the pig parasites produce nodules in the intestine.

Heavy infections in cattle and pigs cause diarrhœa, listlessness and loss of weight. In the case of cattle it is usually found that there are other worms as well, for instance *Hæmonchus*, *Cooperia* and *Bunostomum*, and the symptoms are due to the total infection. Of importance is also the fact that the nodules make the intestines useless as sausage casings.

For treatment phenothiazine (p. 171) is effective. Spindler, Zimmerman and Hill* found that feeding pigs on skim milk only for 3-5 days causes purgation and evacuation of large numbers of nodular and whipworms. There is no loss of weight during the treatment. The authors recommend such treatment at monthly intervals where sufficient milk is available.

Genus **Chabertia** Railliet and Henry, 1909

17 **C. ovina** (Gmelin, 1790) occurs in the colon of sheep, goats, cattle and a number of other ruminants. Male 13-14 mm. long, female 17-20 mm. long. The anterior end is curved slightly ventrad and the large buccal capsule opens antero-ventrally. The oral aperture is surrounded by a double row of small cuticular elements representing the leaf-crowns. There is a shallow ventral cervical groove, and anterior to it a slightly inflated cephalic vesicle. The male bursa is well developed and the spicules are 1·3-1·7 mm. long, with a gubernaculum. The vulva of the female opens about 0·4 mm. from the posterior extremity. The eggs measure 90-105 by 50-55 μ.

Life-Cycle.—Direct, resembling that of *Strongylus equinus* as far as the free stages are concerned. The sheath of the infective larva has a relatively long tail. Infection of the host occurs per os. No migration in the body takes place as far as is known.

Pathogenesis, Symptoms and Lesions.—The worms attach themselves firmly to the mucosa of the colon by means of their buccal capsules and, according to Wetzel,† draw in a plug of the

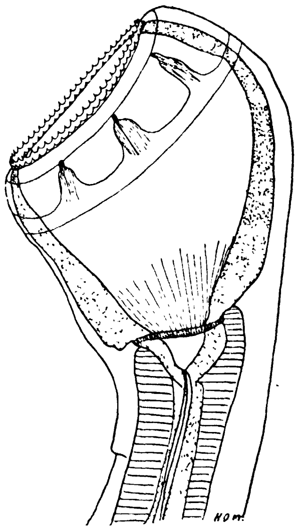

FIG. 106.—*Chabertia ovina*, ANTERIOR END, LATERAL VIEW. (ORIGINAL.)

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* *Proc. Helm. Soc. Wash.*, 11 (1): 9. 1944. † *North Amer. Vet.*, 12 (9): 3 pp. 1931.

mucosa, chiefly the stratum glandulare, which is digested by the secretions of the œsophageal glands of the worm. According to this author the worms suck blood by accident only, in case a bloodvessel should be ruptured. The adjoining parts of the mucosa show an increased activity of the goblet cells and infiltration with lymphocytes and eosinophiles. The worms appear to move about frequently, causing extensive destruction of the mucosa, and in this way they may allow bacteria to enter the tissues. The parasites are also suspected of having a toxic action. At autopsy the worms are found attached to the mucosa of the colon, which is congested, swollen and covered with a transparent mucus in severe cases, while punctiform hæmorrhages may be present. In severe infections the sheep lose condition and may become anæmic and die.

Diagnosis is made by finding the eggs in the fæces and by identification of the larvæ in fæcal cultures.

Treatment.—Phenothiazine (p. 171) gives the best results. Tetrachlorethylene will probably also be effective.

Prophylaxis.—See under œsophagostomiasis (p. 180).

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Genus Stephanurus Diesing, 1839

S. dentatus Diesing, 1839, the "kidney-worm" of swine, occurs in the perirenal fat, the pelvis of the kidney and the walls of the ureters, and as an erratic parasite in the liver or other abdominal organs and sometimes the thoracic organs, as well as the spinal canal of the pig; it is rarely seen in the liver of cattle and has also been reported from a donkey. The parasite is widely distributed in tropical and subtropical countries. Male 20-30 mm., female 30-45 mm. long. The worms are stout, the female being about 2 mm. broad, and the internal organs are partly visible through the cuticula. The buccal capsule is cup-shaped and thick-walled with six variably cusped teeth at its base. Its rim bears a leaf-crown of small elements and six external cuticular thickenings or "epaulettes," of which the dorsal and ventral are the most prominent. The male bursa is small and its rays are short. The two spicules are equal or unequal and measure 0·66-1 mm. in length. The vulva is situated close to the anus. The eggs measure about 100 by 60 μ.

Life-Cycle.—In their normal habitat the adult worms are lodged in cysts which communicate with the ureters, so that the eggs are passed out in the urine of the host. At this stage the embryo consists of about 32-64 cells. The development of the pre-infective stages is similar to that of *Strongylus equinus* (p. 164). At an optimum temperature of 26° C., and if sufficient oxygen is available, the eggs hatch after 24-36 hours and the larvæ reach the infective stage about 4 days later after two ecdyses, retaining the second skin as a sheath. The eggs and all larval stages are rapidly killed by freezing and dryness. The infective larvæ can live in moist surroundings up to 5 months, but the majority die off after 2-3 months. Under wet conditions they live a shorter period and they are also adversely affected by sunlight. They show little negative geotropism.

The complicated development of the parasitic stages has been studied especially by Schwartz and Price* in America and by Ross and Kauzal† in Australia. Infection of the host occurs per os or through the skin. The sheath of the infective larva is cast soon after infection has occurred and the third ecdysis takes place about 70 hours later, either in the wall of the stomach, after oral infection, or in the skin and the abdominal muscles after percutaneous infection. The fourth-stage larva possesses a buccal capsule. From both ports of entry the larvæ reach the liver: after oral infection via the portal vessels in 3 days or longer, and after skin penetration via the lungs and the systemic circulation in 8-40 days. Normally the larvæ escape from the hepatic vessels and wander through the liver parenchyma until they reach the surface. They wander about underneath the liver capsule and eventually, 3 months or more after infection, penetrate through the latter into the peritoneal cavity. After having reached the perirenal tissues they perforate the walls of the ureters, in order to establish connection with the external world, and then live in the renal region in cysts which communicate with the ureters through fine canals.

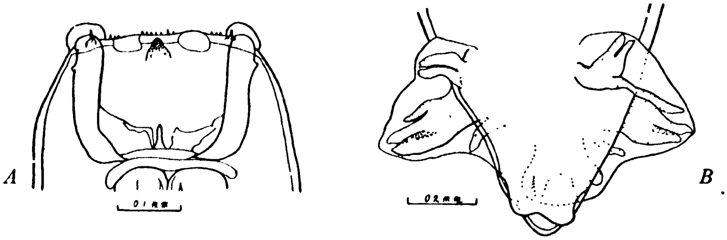

Fig. 107.—*Stephanurus dentatus.* (From Baylis, after Daubney.)
A, anterior end; *B*, posterior end of male, ventral view.

The migrating larvæ have a marked tendency to penetrate soft tissues and many of them go astray. After percutaneous infection some stick in the pulmonary capillaries and become encapsulated in the lungs, or they may wander further and reach the pleural cavity and other thoracic organs. Frequently larvæ attempt to pierce the walls of the portal vessels, the vena cava caudalis or the gastrohepatic artery, causing the formation of thrombi, and the worms may accumulate around these vessels. In the peritoneal cavity they do not all reach the perirenal tissues, but penetrate into other organs like the spleen, psoas muscles, etc.

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* *Journ. Amer. Vet. Med. Assn.*, 34 (3): 325-347. 1932.

† Council for Sc. and Ind. Res., *Bull. No.* 58, pp. 1-80, 20 figs. 1932.

Pathogenesis.—Percutaneous infection causes the formation of nodules in the skin, with œdema and enlargement of the superficial lymph glands. These lesions disappear after 3 or 4 weeks. The migrating larvæ produce lesions of an acute inflammatory nature, which suggests that these may be due to bacteria introduced by the worms from the alimentary canal rather than by the worms alone. The inflammatory processes may take the form of abscesses or give rise to cirrhosis and multiple adhesions of organs; much damage is done in this indirect way. The adult parasite itself is not markedly pathogenic.

Symptoms.—The pathogenic effects of this parasite have not been described in great detail. The temporary skin lesions mentioned above may be seen in the early stages of the infection. Posterior paralysis has been ascribed to the parasite, but this view is not accepted by all authors. When it occurs, it may be due to sensitiveness in the kidney region, as described by Boynton.* This author has also observed a stiffness in the hind-quarters, progressing to lameness and weakness in the loins and paresis or paralysis of the hind-quarters a few days before death. The worm has been found in the spinal canal without causing paralysis. The inflammatory processes, adhesions and abscesses would probably cause some derangement in the function of various organs and a certain degree of toxæmia. Emaciation usually occurs, and in milder cases growth is retarded. Ascites is sometimes present as a result of thrombosis and cirrhosis in the liver. The animals eat fairly well up to a few days before death.

The chief importance of the parasite is that the kidneys, liver and even other organs or whole carcasses may be unfit for human consumption, while carcasses from which the kidneys have been removed may not be acceptable on some markets.

Post-Mortem.—Decomposition takes place rapidly in animals that have died from the results of this infection. Depending on the severity and the stage of the disease, there may be cutaneous nodules, peritonitis of varying degrees with adhesions of the abdominal organs, cirrhosis and abscesses in the liver and elsewhere. Young and even adult worms may be found in cysts or abscesses in the lungs and other thoracic organs or free in the pleural cavity. A venous hyperæmia is seen in the liver, kidneys and portal and mesenteric lymph glands. The liver is enlarged and its surface is uneven on account of the presence of irregular tracks and scars, which are also found deeper in the parenchyma. Cirrhosis may be marked and ascites is then usually present. Thrombi in the hepatic bloodvessels are common and they may contain young stages of the worms or these may have accumulated in the tissues surrounding the vessel. The perirenal tissues usually show a certain degree of hypertrophy and the surface of the kidneys may bear small scars of healed abscesses. The worms are found in and around the kidneys and ureters, as described above. The portal and mesenteric lymph vessels are enlarged, while in older cases they are indurated and have uneven surfaces.

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* *Philippine Journ. Sc.*, Section B, 9 (3): 259-268. 1914.

Diagnosis can be made by finding the eggs of the parasite in the urine of the pig if mature worms are present and in communication with the ureters. In other cases a definite diagnosis can be made at autopsy only.

Treatment.—No satisfactory method of treatment is known. Experiments of Kauzal indicate that carbon tetrachloride may possibly have some effect on the parasites while they are present in the liver.

Prophylaxis is largely a matter of hygiene. It has been found in America that the swine sanitation system as carried out against *Ascaris lumbricoides* brought about a considerable decrease in the incidence of *S. dentatus*, and that it is expedient to provide a hard, bare strip, 1·5-2 metres wide, along the edge of the pasture and to place the shelters and troughs on a bare patch 10 metres wide at the end of the field, since the pigs mostly urinate in these places. Ross and Kauzal state that the larvæ of the parasite are killed by spraying mud of limited depth with a 10 per cent. solution of copper sulphate or a 5 per cent. solution of kerol at the rate of 10 gallons per 100 sq. yards (about 1 litre per 2 sq. metres), and that such treatment was non-toxic for pigs kept in treated yards. All moist and muddy places, especially in shade, must be avoided and they should be drained or filled in. Segregation of clean, especially young, animals from infected ones and periodic unstocking of pens, which are then allowed to dry thoroughly in sunlight, are important measures. Pigs may be kept in concrete-floored sties which are cleaned out and sprayed with one of the above-mentioned solutions at intervals of not longer than a week.

Genus Syngamus v. Siebold, 1836

19 **S. trachea** (Montagu, 1811), the "gapeworm," occurs in the trachea of the turkey, fowl, pheasant, guinea-fowl, goose and various wild birds. The parasites are bright red in colour when fresh and the sexes are found permanently in copulation. Male 2-6 mm., female 5-20 mm. long. The mouth opening is wide, without leaf-crowns, and the buccal capsule is cup-shaped, bearing six to ten small teeth at its base. The male bursa has short, stout rays. The spicules are 0·053-0·082 mm. long, equal and simple in shape. In the female the vulva opens in the anterior

third of the body, while the coils of the uterus and ovaries lie behind this level. The eggs, which measure 78-110 by 43-46 μ, are provided with a thickened operculum at either pole and are ejected from underneath the male bursa in the 16-celled stage.

Life-Cycle.—The eggs of the worms are usually coughed up and swallowed by the host, thus passing out in the fæces. Under optimal conditions of moisture and temperature the embryo develops to a larva in about 3 days. According to Wehr* the larva moults twice in the egg and will hatch, if conditions are suitable, on the ninth day. The larva retains the cuticle of the previous stage as a sheath and is infective also if it has not hatched from the egg. The infective larva has a short, pointed tail and a relatively long œsophagus. It soon becomes rather inactive and shows no negative geotropism, nor is it able to resist desiccation. Infection of the host occurs per os. The infective larvæ may be swallowed by earthworms, snails, slugs, flies and other arthropods, in which they become encysted and may live for a few years, so that these invertebrates may become heavily infected and act as important transport hosts. According to Morgan and Clapham, passage through earthworms renders the larvæ more highly infective, enabling strains from wild birds to pass to chicks more readily than is otherwise the case.

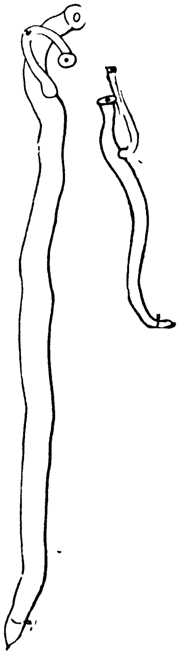

FIG. 108.—*Syngamus trachea*, OUTLINES OF TWO PAIRS OF WORMS. (FROM BAYLIS, AFTER CHAPIN.)

On the right, female immature; on the left, female gravid.

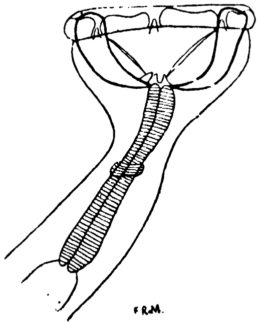

FIG. 109.—*Syngamus trachea*, ANTERIOR END. (FROM BAYLIS, AFTER YORKE AND MAPLESTONE.)

The larvæ reach the lungs via the blood and live in the alveoli.

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* *Poultry Sc.*, 16 (5): 331-334. 1937.

A further ecdysis occurs on the third day after infection, after which the sexes can be differentiated. The final ecdysis occurs on the fourth or fifth day and the young worms migrate to the larger bronchi, where copulation takes place. The trachea is reached as early as the seventh day and the first eggs are found in the fæces of the host from 17-20 days after infection.

Pathogenesis.—In heavy infections migration through the lungs may cause ecchymoses, œdema and even lobar pneumonia. In the trachea the worms attach themselves to the mucosa and suck blood, with consequent catarrhal tracheitis and the secretion of much mucus. The males become deeply embedded with their anterior ends in the wall of the trachea of turkeys, causing the development of nodules.

Symptoms.—Turkeys are susceptible to infection at any age, but show no symptoms and are therefore dangerous carriers of the disease. Chicks, goslings and pheasants suffer most from the parasites, while adult fowls are usually not susceptible to infection. The characteristic symptoms of " gapes " are those of dyspnœa and asphyxia, occurring in spasms on account of the accumulation of mucus in the trachea. The bird shakes and tosses its head about and it may cough, or it extends the neck, opens the beak and performs gaping movements. Death results from asphyxia during such an attack or from progressive emaciation, anæmia and weakness caused by the parasite.

Post-Mortem.—The carcass is emaciated and anæmic and the worms are found in the posterior part of the trachea, attached to the mucosa and surrounded by mucus which may be streaked with blood.

Diagnosis can be made from the symptoms and by finding in the fæces the characteristic eggs, which must be differentiated from those of Capillarias. As a rule the diagnosis will be further confirmed by finding the worms at the autopsy of a selected case.

Treatment.—The best remedy is barium antimonyl tartrate, according to Wehr, Harwood and Schaffer.* The chicks are placed in a suitable container and the powdered drug is blown into the air of the closed container several times. Clapham† recommends $\frac{1}{3}$ minim allyl sulphide in the form of a 1 : 3 solution in linseed oil, given per os thrice daily and giving about five doses in all. The remedy causes the worms to be ruptured and then coughed up. The eggs of such worms were found to be sterile. Taylor describes the extraction of the worms by means of a fine brass wire spiral, with which he has had much success.

Prophylaxis.—Infected birds which cannot be treated should be killed and the heads, the respiratory and the digestive organs destroyed by burning. The clean birds are best removed to fresh ground. Moist localities where earthworms, slugs and snails occur should be avoided if possible, and it is advantageous not to let chicks out before the dew is off the grass. Turkeys should not be kept on the same ground as fowls or even near to them. When new chicks are introduced they should be purchased out of clean flocks or otherwise quarantined and examined for the presence of the parasite. Wild birds, especially starlings, which may harbour the parasite, should be prevented from introducing the infection into the fowl-run.

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* *Journ. Par.*, 24 (6): Suppl.: 17. 1938.

† *Journ. Helm.*, 13(1): 3-8. 1935.

S. laryngeus Railliet, 1899, occurs in the larynx of cattle and buffaloes in India, Malaya and South America, and has also been reported from man. The affected animals cough and lose condition and calves especially may develop bronchitis.

S. nasicola v. Linstow, 1899, has been found in the nasal cavities of sheep, cattle, goats and deer in Brazil, Africa, Turkestan and the West Indies.

Genus Cyathostoma E. Blanchard, 1849

C. bronchialis (Muehlig, 1884) occurs in the trachea and bronchi of the goose, duck and swan. These worms are not permanently in copula. Male 4-5·8 mm., female 16-31 mm. long. The buccal capsule is cup-shaped with 6-7 teeth at its base. The male bursa is well developed and the spicules are 0·51-0·62 mm. long. The eggs measure 74-83 by 49-62 μ.

Life-cycle unknown.

Pathogenicity.—The parasite is very harmful, especially to young geese, producing loss of appetite and condition as well as dyspnœa and asphyxiation.

Treatment and Prophylaxis.—As in the case of *Syngamus trachea.*

Family ANCYLOSTOMIDÆ

Strongyloidea with a well-developed buccal capsule, which is devoid of leaf-crowns, but is armed at its ventral margin with teeth or chitinous plates. The anterior extremity is usually bent dorsad, hence the name "hookworms." The male bursa is normally developed.

Genus Ancylostoma Dubini, 1843

A. caninum Ercolani, 1859, occurs in the small intestine of the dog, cat, fox and very rarely also in man. It is cosmopolitan in distribution. Male 10-12 mm., female 14-16 mm. long. The worms are fairly rigid and grey or reddish in colour, depending on the presence of blood in the alimentary canal. The anterior end is bent dorsad and the oral aperture is directed antero-dorsally. The buccal capsule is deep. Its ventral margin is provided with three teeth on either side, and in the depth of the capsule there is a pair of triangular dorsal teeth. The male bursa is well developed and the spicules are about 0·9 mm. long. The vulva is situated near the junction of the second and last thirds of the body. The uteri and ovaries form numerous transverse coils in the body. The eggs measure 56-65 by 37-43 μ and contain an embryo of about eight cells when laid.

A. braziliense Gomez de Faria, 1910 (syn. *A. ceylanicum* Looss, 1911), occurs in the small intestine of the dog, cat, fox and sometimes man, and is found in most tropical and subtropical countries. It is slightly smaller than *A. caninum*, the males measuring 6-7·75 mm. and the females 7-10 mm. It can be differentiated from the previous species by the fact that its ventral teeth consist of a large and a small one on either side. The eggs measure 75-95 by 41-45 μ.

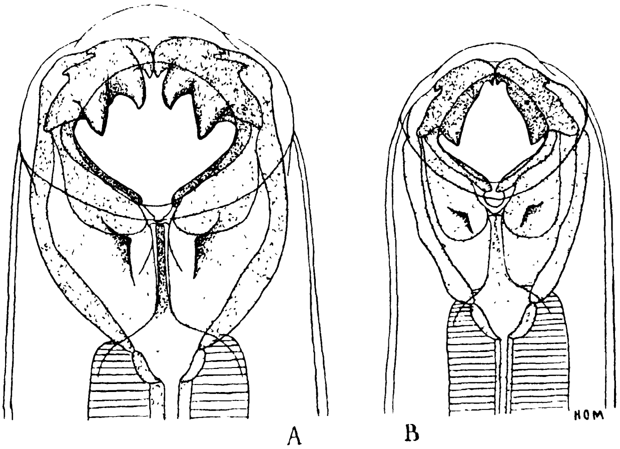

FIG. 110.—ANTERIOR END, DORSAL VIEW, OF A, *Ancylostoma caninum*; B, *A. brasiliense*. (ORIGINAL.)

A. duodenale Dubini, 1843, one of the hookworms of man occurring in all tropical and subtropical countries, has also been recorded from certain wild carnivora and the pig. Experimental infection of young dogs and cats has been successful, but the parasite does not normally occur in these hosts. The ventral teeth of this worm consist of two large and one small one on either side.

Life-Cycle.—The pre-infective stages develop and react like those of *Strongylus equinus* (p. 164), but none of them, not even the infective larvæ, are resistant to desiccation, and are therefore found only in moist surroundings. The infective stage is reached within a week if the temperature is suitable, and it enters the host either through the skin or through the mouth. In the former case the larvæ reach the blood, which carries them via the heart to the lungs. Here the majority will become arrested in the capillaries, from which they pass to the alveoli and then up the respiratory passages to the pharynx and down again to the intestine, like *Ascaris* larvæ, increasing in size during their migration. Some larvæ may pass through the pulmonary capillaries and reach the systemic circulation. They are then carried to various organs, in which they cause small hæmorrhages and later die, or, in a pregnant animal, they may reach the fœtus and establish a prenatal infection. After oral infection the larvæ may also migrate through the lungs, but those of *A. caninum* frequently penetrate into the wall of the stomach or intestine and remain there for a few days before they return to the lumen. The worms reach the adult stage in the host in about 5 weeks.

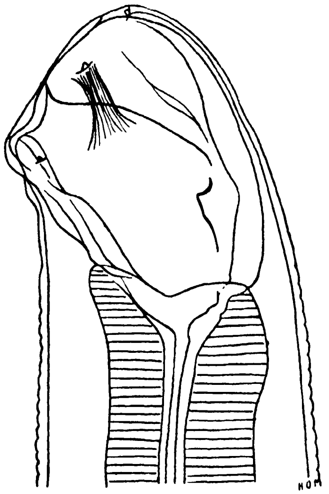

FIG. 111.—*Uncinaria stenocephala*, ANTERIOR END, LATERAL VIEW. (ORIGINAL.)

Genus **Uncinaria** Fröhlich, 1789

U. stenocephala (Railliet, 1884) is a hookworm found in the dog, cat and fox in Europe and North America. Male 5-8·5 mm., female 7-12 mm. long. The worm resembles *Ancylostoma*, but has a pair of chitinous plates at the ventral border of the buccal capsule instead of teeth. The male bursa is well developed, and the spicules are slender and 0·64-0·76 mm. long. The eggs measure 65-80 by 40-50 μ.

Life-Cycle.—Direct, resembling that of *Ancylostoma.*

ANCYLOSTOMIASIS AND UNCINARIASIS IN DOGS, CATS AND FOXES

Pathogenesis.—In animals that have some degree of immunity, as after a previous infection, the entrance of larvæ through the skin may give rise to a marked local reaction in the skin and subcutis. Pulmonary lesions due to migrating larvæ are usually not as severe as in the case of ascariasis. The adult parasites attach themselves to the mucosa of the intestine and suck blood. They inject into the wound the secretions of their cephalic or œsophageal glands which prevent coagulation, so that the wound continues to bleed for some time after the worm has moved to another place. Wells* has observed that the worm (*A. caninum*) fills its intestine with blood and then ejects it through the anus at more or less regular intervals. He has calculated that one worm would remove about 0·8 c.c. of blood in 24 hours, so that in a severe infection a large proportion of the host's blood will be lost daily. This author is inclined to think that the process of blood-sucking subserves mainly a respiratory function and that the worm further utilises only simple, diffusible substances prepared for assimilation by the host, since erythrocytes in the blood are ejected by the worm. This marked blood-sucking action of the parasites would sufficiently account for the severe anæmia and associated changes in the blood of the host, and it has been shown by several investigators that the main effect of the parasites is to deplete the body of iron, thus preventing the further formation of erythrocytes.

Symptoms.—Ancylostomiasis and uncinariasis occur chiefly in summer and especially in animals that are confined on a relatively small area of moist ground, like dogs in kennels and foxes in runs. It is seen in animals of all ages, but usually not, like ascariasis, in very young pups; however, prenatal infection may cause a sudden onset of severe anæmia, coma and death about 3 weeks after birth. In foxes it occurs usually when they are 2-6 months old. The disease may be acute and rapidly fatal in susceptible animals, while others may develop a marked degree of resistance to the effects of infection, which may, however, be broken down by an intercurrent disease or adverse conditions. The chief symptom is anæmia, accompanied by hydræmia, sometimes œdemas, general weakness and emaciation. In the later stages of the disease the blood changes may include eosinophilia. Growth is stunted and the coat becomes dry and harsh; in foxes the fur is poor. Itching of the skin and areas of dermatitis may be observed. The fæces are often diarrhœic and contain bloody mucus, or they may be of a tarry nature. It has been calculated that as much as one-third of the hæmoglobin in the body may be lost daily through the fæces. Death is as a rule preceded by marked weakness, particularly in the hind-quarters, and extreme paleness of the mucous membranes.

Post-Mortem.—Anæmia and cachexia are conspicuous, while œdemas and ascites are frequently seen. The liver has a light brown colour and shows fatty changes. The intestinal contents are hæmorrhagic. The mucosa is usually swollen, covered with mucus, and shows numerous small red bite marks of the worms. The latter are found attached to the mucosa, or sometimes free, and their colour is grey or reddish, depending on the amount of blood in their intestines.

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* *Journ. Parasitol.*, 17 (4): 167-182. 1931.

Diagnosis is made from the symptoms and confirmed by finding the eggs of the worms in the fæces.

Treatment.—In severe cases blood transfusion may be required. In other bad cases a course of iron tonic may be necessary before anthelmintic treatment can be given. Carbon tetrachloride at the rate of 0·3 c.c. or tetrachlorethylene 0·3 c.c. per kilo bodyweight with a maximum of 3 c.c. are the most satisfactory drugs. The latter is especially indicated for foxes, cats and young dog pups. The drugs should be administered with the usual precautions (p. 50), given in gelatin capsules and, if possible, followed immediately by a dose of concentrated magnesium sulphate solution, or by a dose of arecoline, as for tapeworms, half an hour later. An iron tonic is essential to promote rapid recovery.

Prophylaxis.—Since the pre-infective stages are not resistant to desiccation, the ground on which susceptible animals are kept should be as dry as possible and fæces should be removed at short intervals. In fox-runs high grass is undesirable, since it assists in keeping the ground moist and the infective larvæ migrate on to it after dew has fallen and if the temperature is not too low, thus increasing the chances of infection. Foxes should not be fed under such conditions while there is dew on the grass, and, according to Sprehn, especially not within a few hours after sunrise. The floors of kennels could be treated with common salt which kills the larvæ.

Creeping Eruption.—This condition occurs in man and is characterised by the presence of progressively developing thickened tracks in the skin, accompanied by marked pruritus. It is caused by wandering larvæ of the nematodes *Ancylostoma braziliense* and *Uncinaria stenocephala*, species of *Gnathostoma*, the young maggots of the Œstrid flies *Gastrophilus hæmorrhoidalis*, *G. intestinalis* and *Hypoderma bovis*, while one case due to the Acanthocephalid *Echinorhynchus sphærocephalus* has been recorded, and a similar condition can also be caused by certain ants and mites. Papular skin lesions have also been produced experimentally with larvæ of *Ancylostoma caninum.* The most frequent cause is apparently the larva of *A. braziliense.* Creeping eruption is seen most frequently in warm climates and where moist, sandy soil is found. It occurs chiefly on the feet, legs and the gluteal region of children. The condition is important from the veterinary aspect on account of the prophylactic measures which may have to be instituted against it, by removing the source of infection.

Genus **Agriostomum** Railliet, 1902

A. vryburgi Railliet, 1902, occurs in the small intestine of the zebu (*Bos indicus*) and perhaps the ox in India and Sumatra. Male 9·2-11 mm., female 13·5-15·5 mm. long. The buccal capsule opens antero-dorsally, and is relatively shallow. It is followed by a very large œsophageal funnel which contains two small subventral lancets. The oral margin is provided with four pairs of large teeth and a rudimentary leaf-crown. The bursa is well developed; the ventral rays are close together and parallel; the antero-lateral ray is short, thick and divergent from the other laterals; the dorsal bifurcates twice. Spicules equal, 0·83-0·87 mm. long and accompanied by a gubernaculum. The vulva is posterior and eggs measure 125-195 by 60-92 μ.

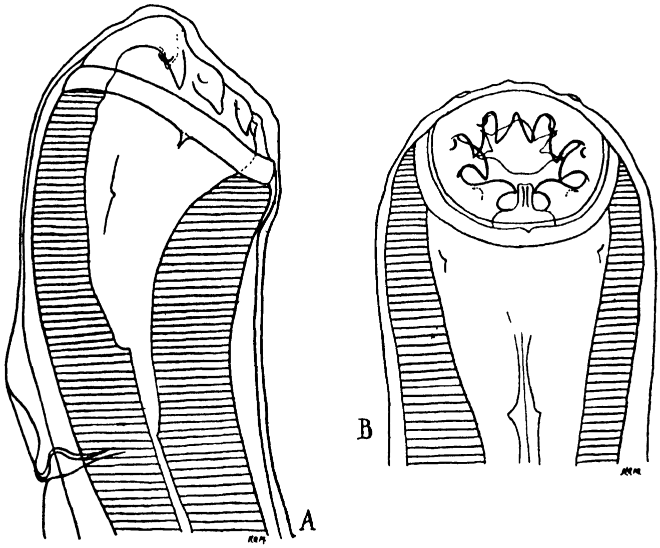

Fig. 112.—*Agriostomum vryburgi.* (Original.)
A, Anterior end, lateral view; B, anterior end, dorsal view.

Life-Cycle.—Probably direct.

Pathogenicity.—Little is known about this, but the parasites will undoubtedly be harmful blood-suckers and cause symptoms like other hookworms in heavy infections.

Genus Necator Stiles, 1903

N. americanus (Stiles, 1902) is a common hookworm of man, occurring in most warm climates, especially in America and Africa. It has also been recorded from the dog. The parasite is relatively unimportant from the veterinary aspect, but it is a cause of severe hookworm disease in man.

N. suillus Ackert and Payne, 1922, occurs in the pig in Trinidad.

Genus **Bunostomum** Railliet, 1902 (syn. *Monodontus*)

B. trigonocephalum (Rudolphi, 1808) is a hookworm which occurs in the small intestine (ileum and jejunum) of sheep and goats in many parts of the world and in Scottish red deer. It has also been recorded from cattle, but the accuracy of this record seems to be doubtful. Male 12-17 mm., female 19-26 mm. long. The buccal capsule opens antero-dorsally; it is relatively large and bears at its ventral margin a pair of chitinous plates. Near its base is a large dorsal tooth, pierced by the duct of the dorsal œsophageal gland, and a pair of smaller subventral lancets. The bursa is well developed and has an asymmetrical dorsal lobe. The right externo-dorsal ray arises higher up on the dorsal stem and is longer than the left. The spicules are slender, alate and 0·6-0·64 mm. long. The vulva opens a short distance in front of the middle of the body. The eggs measure 79-97 by 47-50 μ (usually 92 by 50 μ), the ends are bluntly rounded and the embryonic cells darkly granulated. The eggs can be differentiated from those of other worms in fresh sheep fæces.

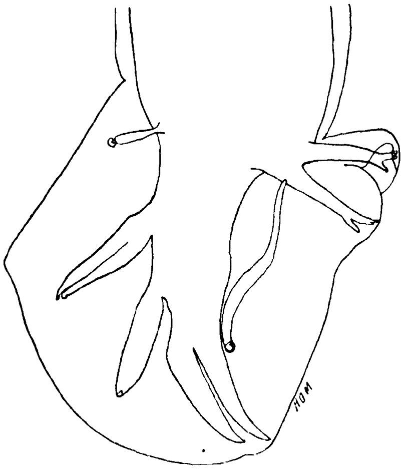

FIG. 113.—*Necator americanus*, HIND END OF MALE, LATERAL VIEW. (ORIGINAL.)

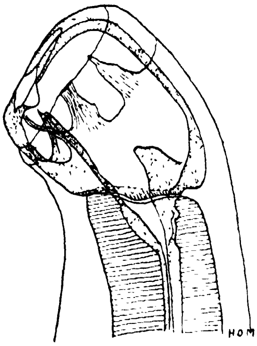

FIG. 114.—*Bunostomum trigonocephalum*, ANTERIOR END, LATERAL VIEW. (ORIGINAL.)

Life-Cycle.—The development is direct and similar to that of *Strongylus equinus* (p. 164), but none of the free-living stages can resist desiccation. The infective larva is sheathed. It has a relatively short body and a long tail to the sheath (p. 180), while the œsophagus bears a rather prominent posterior bulbar thickening. Infection of the host occurs per os and via the skin, as shown by Ortlepp,* who also found that the larvæ pass to the lungs, where the third ecdysis occurs. The fourth-stage larvæ, which have a buccal capsule, reach the intestine again after 11 days and the first eggs are passed about 10 weeks after infection occurred.

Pathogenesis.—As in the case of ancylostomiasis, described above, the adult worms attach themselves to the intestinal mucosa and suck blood. It is probable that they pump out the blood of the host like *A. caninum.* The worms inject an anticoagulatory substance into the wound, and a hæmolytic toxin has been described from the blood of infected sheep.

Symptoms.—The main symptoms are progressive anæmia, with associated changes in the blood picture, hydræmia and œdemas, which show especially in the intermandibular region as a "bottle-jaw." The animals become weak and emaciated and the appetite usually decreases. The skin is dry and the wool of sheep falls out in irregular patches. Diarrhœa is not infrequent, and the fæces may be dark in colour on account of the presence of altered blood pigments. Death is frequently preceded by complete prostration, which may last for several days.

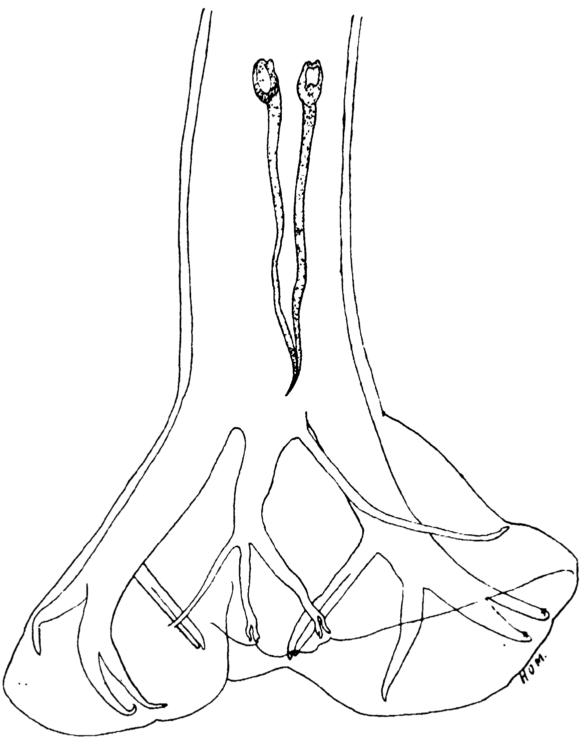

FIG. 115.—*Bunostomum trigonocephalum,* HIND END OF MALE, DORSAL VIEW. (ORIGINAL.)

Post-Mortem.—The picture is very similar to that described under ancylostomiasis. In addition, hydrothorax and hydropericard are commonly seen.

Diagnosis is made partly from the symptoms, but must be differentiated from other verminoses producing anæmia by the identification of the eggs in the fæces.

* *Ond. J. Vet. Sc. Anim. Ind.,* 8 (1/2): 183-212. 1937.

Treatment.—Phenothiazine (p. 171) is effective. 7·5 c.c. tetrachlorethylene for sheep over 9 months, 5 c.c. for lambs, mixed with an equal quantity of liquid paraffin, or a tetrachlorethylene emulsion containing the requisite quantity of the drug, given immediately after 2·5 c.c. 10 per cent. copper sulphate solution and repeated twice with intervals of 10-14 days, gives good results. The sheep need not be starved, but must be treated when it is cool and must not be driven long distances before or after treatment. In addition the sheep should receive a tonic lick containing 2-3 per cent. of iron sulphate as long as there is anæmia.

Prophylaxis.—In general, the measures described on p. 180 should be applied. Since the infective larvæ cannot resist dryness, the infection is found invariably on permanently or occasionally moist pastures and can therefore be readily controlled by avoiding such places, which should be drained if possible. Around watering troughs the ground should be kept hard and dry or treated frequently with liberal applications of salt.

B. phlebotomum (Railliet, 1900) is widely distributed and occurs in the small intestine, mainly in the duodenum of cattle and the zebu, and has also been recorded from sheep, but the accuracy of this is doubtful. Male 10-18 mm., female 24-28 mm. long. It closely resembles the preceding species, but can be differentiated by the presence of two pairs of subventral lancets in the buccal capsule and the longer male spicules, which measure 3·5-4 mm. The eggs measure about 106 by 46 μ, have blunt ends and darkly pigmented embryonic cells, so that they can be readily differentiated from other worm eggs in the fæces.

Life-Cycle.—Similar to that of *B. trigonocephalum.*

Pathogenesis and Symptoms.—As described in the case of the preceding species. Sigetwary mentions as the most characteristic symptom in stabled cattle an itching of the legs, which causes the animals to stamp their feet and lick their legs. At first symptoms of colic are usually seen, accompanied by constipation. This is later followed by diarrhœa, anæmia and marked weakness, especially in calves.

Diagnosis has to be confirmed by finding the eggs in the fæces.

Treatment.—Phenothiazine (p. 171) is effective. Good results have been obtained by administering, immediately after 300 c.c. of a 5 per cent. sodium bicarbonate solution, a tetrachlorethylene emulsion at the dose rate of 10 c.c. tetrachlorethylene per 50 kilos with a maximum of 30 c.c. of the drug. An iron tonic is indicated.

Prophylaxis.—As in the case of *B. trigonocephalum.* Stabled cattle should be protected by hygienic measures, especially by frequent removal of fæces, by keeping the floors and bedding dry, and preventing contamination of the food and water.

Genus **Gaigeria** Railliet and Henry, 1910

G. pachyscelis Railliet and Henry, 1910, is a hookworm which occurs in the duodenum of sheep and goats in India and Africa. Male up to 20 mm., female up to 30 mm. long. In general it resembles *Bunostomum trigonocephalum.* The buccal capsule contains a large dorsal tooth and a pair of subventral lancets which have several cusps each. The male bursa has small lateral lobes and a voluminous dorsal lobe which is supported by stout dorsal rays, each ending in about three small digitations. The spicules are relatively slender and 1·25-1·33 mm. long. The eggs measure 105-129 by 50-55 μ and have blunt ends.

Life-Cycle.—Direct and similar to that of other hookworms. The infective larvæ are sheathed and resemble those of *Bunostomum trigonocephalum.* They have no resistance against desiccation. According to Ortlepp* infection occurs only through the skin. The larvæ reach the lungs via the blood, where the third ecdysis occurs and they remain for about 13 days. The fourth-stage larva, which has a globular buccal capsule with a dorsal tooth and a pair of subventral lancets, then creeps up the bronchi and trachea to the pharynx and is swallowed down, reaching the intestine, where the fourth ecdysis occurs and the worms grow adult in about 10 weeks from the time of infection.

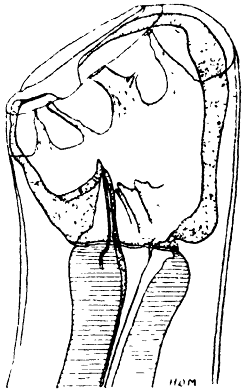

FIG. 116. — *Gaigeria pachyscelis*, ANTERIOR END, LATERAL VIEW. (ORIGINAL.)

Pathogenicity, Symptoms, etc.—Similar to *Bunostomum trigonocephalum.* The worms are exceedingly virulent blood-suckers and about 24 are sufficient to cause death. The parasite is more pathogenic to merinos than to the hairy breeds of sheep, such as Persians. In severe infections death occurs suddenly, the only symptom being anæmia. In more chronic cases the usual symptoms of hookworm infection are seen. The worms are found attached to the mucosa of the first part of the small intestine, frequently in groups of 2-3, the groups lying some 20 cm. apart, and surrounded by a quantity of fresh blood. Observations made in South-West Africa indicate that the larvæ, penetrating through the skin of the feet of sheep, are instrumental in introducing the germs of foot-rot.

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* *Ond. J. Vet. Sc. Anim. Ind.*, 8 (1/2) 183-212. 1937.

Diagnosis can be made by finding the characteristic eggs in the fæces.

Treatment.—As described for *Bunostomum trigonocephalum.*

Prophylaxis.—Moist pastures and all moist ground should be avoided.

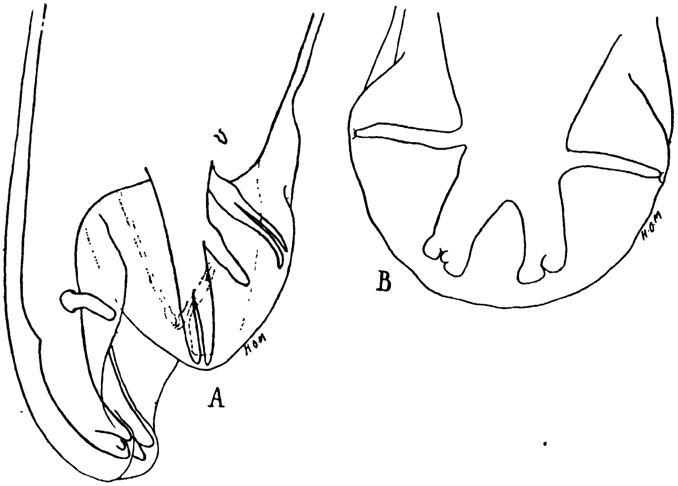

FIG. 117.—*Gaigeria pachyscelis.* (ORIGINAL.)
A, Hind end of male, lateral view; B, dorsal lobe of male bursa with dorsal rays.

Since infection occurs via the skin only it is essential that the surroundings of watering troughs should be kept dry or be treated with salt. The parasites could be exterminated by cleaning the sheep during dry periods, since the larvæ are not resistant to desiccation. In South Africa the distribution of the parasite is closely associated with sandy soil.

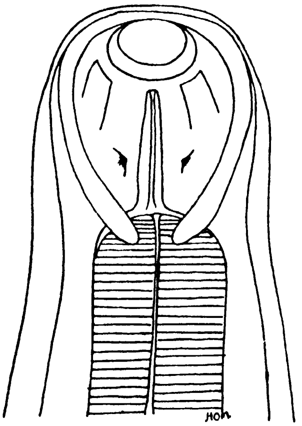

FIG. 118.—*Globocephalus urosubulatus*, DORSAL VIEW OF ANTERIOR END. (ORIGINAL.)

Genus **Globocephalus** Molin, 1861

Several species of this genus occur in the small intestine of the pig. They are found especially in Eastern countries (India, Samoa, New Guinea and Java), but have also been recorded from Europe, Africa and America. The worms are about 4-8 mm. long and fairly stout. The mouth opens subdorsally and the buccal capsule is globular or funnel-shaped. There are neither leaf-crowns nor teeth at the oral margin. Near the base of the buccal capsule a pair of subventral teeth are usually present, but they may be small or absent in some specimens. The dorsal gutter is prominent, extending almost to the oral margin. The male bursa is well developed, the spicules are slender and a gubernaculum is present. The vulva is situated posteriorly.

Life-Cycle.—Probably direct.

Pathogenicity.—Very little is known about this.

Family AMIDOSTOMIDÆ

Strongyloidea which may have a shallow buccal capsule devoid of leaf-crowns; the male bursa is well developed.

Genus **Amidostomum** Railliet and Henry, 1909

A. anseris (Zeder, 1800) (syn. *A. nodulosum*) occurs in domestic and wild geese and ducks in the mucosa of the gizzard and sometimes also the proventriculus and the œsophagus. The worms are slender and reddish in colour. Male 10-17 mm., female 12-24 mm. long. The buccal capsule is short, wide and thick-walled, with three pointed teeth at its base. The male bursa has divergent ventral rays, long medio- and postero-laterals, while the dorsal is bifurcate distally and the externo-dorsal rays arise along with the laterals. The spicules are 0·2-0·3 mm. long and each ends in two branches. The vulva is situated at the posterior fifth of the body and may be covered by a flap. The eggs measure about 105 by 56 μ and contain a segmenting embryo when laid.

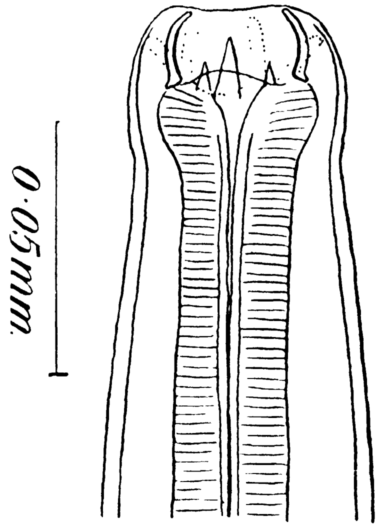

FIG. 119. — *Amidostomum anseris*, ANTERIOR END, DORSAL VIEW. (AFTER BAYLIS.)

Life-Cycle.—Probably direct like that of other strongyles.

Pathogenesis.—The worms are very pathogenic to young geese, while the adult birds may act as carriers of the infection without showing symptoms. The parasites burrow into the mucous and submucous tissues of the gizzard and proventriculus, sucking blood and causing marked irritation, inflammatory changes and hæmorrhage. Ullrich[*] considers that the worms have a marked toxic effect on the host.

Symptoms.—Heavily infected animals lose their appetite and become emaciated, anæmic, weak and easily tired. Diarrhœa is not unusual. Death is often preceded by prostration. According to Ullrich cerebellar ataxia, resulting in inco-ordinated movements of the neck and head and a swaying gait, is frequently observed.

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[*] *Prager Arch. f. Tiermed.*, 12 (3): 61-68. 1932.

Post-Mortem.—The feathers around the anus are soiled and matted with fæces. The carcass is anæmic and emaciated. The horny lining of the gizzard forms a necrotic, fragile mass with a brownish colour, probably due to the admixture of blood pigments. The worms are found partly buried in the necrotic mass. The propria mucosa shows hæmorrhages and localised infiltrations with mononuclear and polynuclear leucocytes.

Diagnosis.—At the present stage of our knowledge a definite diagnosis could be made only by autopsy of a selected case.

Treatment.—Ullrich recommends 2-3 c.c. carbon tetrachloride, administered in a mixture of flour and water as vehicle.

Prophylaxis.—General hygienic measures are indicated and special attention should be given to young ducks. Treatment of the adult birds before the breeding season is recommended.

Family TRICHOSTRONGYLIDÆ

Strongyloidea in which the buccal capsule is absent or very small and is devoid of leaf-crowns, and usually bears no teeth. The male bursa is well developed.

Genus **Trichostrongylus**

The species of this genus are small, slender, pale reddish-brown worms without a specially marked-off " head." There is no buccal capsule. The excretory pore is usually situated in a conspicuous ventral notch near the anterior extremity. The male bursa has long lateral lobes, while the dorsal is not well defined. The ventro-ventral ray is conspicuously smaller than the latero-ventral and the two rays are widely separated, while the dorsal ray is slender and cleft distally. The spicules are pigmented brown, stout and ridged and a gubernaculum is present. The vulva opens a short distance behind the middle of the body and the uteri are opposed (amphidelph). The eggs are oval, thin-shelled and segmenting when laid.

T. colubriformis (Giles, 1892) (syn. *T. instabilis*) occurs in the anterior portion of the small intestine and sometimes also in the abomasum of sheep, goat, cattle, camel and various antelopes. It has also been recorded from the rabbit (*Lepus californicus melanotis*), the pig, the dog and man. Male 4-5·5 mm., female 5-7 mm. long. Spicules equal, 0·135-0·156 mm. long. The eggs measure 75-86 by 34-45 μ.

T. falculatus Ransom, 1911, occurs in the small intestine of sheep and goat and some antelopes. Spicules subequal, about 0·1 mm. long.

T. vitrinus Looss, 1905, occurs in the small intestine of sheep, goat, rabbit, camel and man. Spicules equal, 0·16-0·17 mm. long.

T. capricola Ransom, 1907, occurs in the small intestine of sheep and goat. Spicules equal, 0·13-0·145 mm. long.

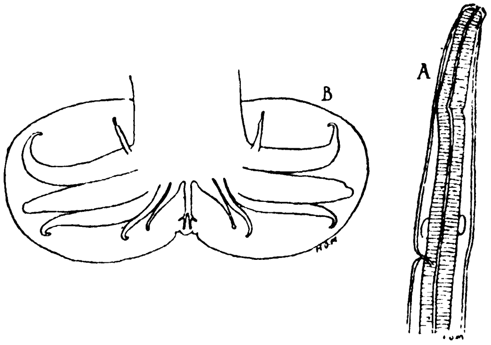

FIG. 120.—*Trichostrongylus instabilis*. (ORIGINAL.)

A, Anterior end, lateral view; B, bursa of male opened out.

T. probolurus (Railliet, 1896) occurs in the small intestine of sheep, camel and man. Spicules equal, 0·126-0·134 mm. long.

T. axei (Cobbold, 1879) (syn. *T. extenuatus*) occurs in the abomasum of sheep, goats, cattle, deer and wild antelopes and in the stomach of the pig, horse, donkey and man. The spicules are unequal and dissimilar, the right is 0·085-0·095 mm. long and the left 0·11-0·15 mm.

T. rugatus Mönnig, 1925, occurs in the small intestine of sheep and goat. Spicules unequal and dissimilar, the right is 0·137-0·145 mm. long and the left 0·141-0·152 mm.

Life-Cycle.—When the eggs are passed in the fæces of the host the embryo consists of 16-32 cells. The development* and bionomics† of the free-living stages resemble those of *Strongylus equinus* (p. 164). The infective stage is reached in about 3-4 days under suitable conditions. In the case of some species, if not in all, eggs containing fully formed embryos ready to hatch can withstand desiccation for 15 months or possibly even longer and the infective larvæ are also resistant to dryness, while the other free-living stages are killed when they become dry. The infective larva has a short tail ending in a slight thickening which bears one or more small projections, and it is enclosed in a sheath which has a relatively short tail. For measurements, see p. 181. Infection of the host occurs per os. The larvæ cast their sheaths and penetrate into the mucosa of the small intestine (*T. instabilis* and *T. rugatus*). The third ecdysis is completed about 4 days after infection and the larvæ return to the surface of the mucosa, where they grow adult after another ecdysis. The first eggs are passed by the host about 3 weeks after infection.

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* Mönnig, *11th and 12th Rep. Dir. Vet. Ed. and Res., South Africa*, pp. 231-251. 1927.

† Mönnig, *16th Rep. Dir. Vet. Ed. and Res., South Africa*, pp. 175-198. 1930.

Pathogenesis.—*T. axei* penetrates into the mucosa of the abomasum of ruminants or the stomach in equines and produces irregular, circumscribed thickenings with a finely verrucose surface. The intestinal forms penetrate into the mucosa underneath the epithelium, rarely deeper, producing desquamation, which may be extensive in heavy infections. The worms are blood-suckers, but they are not very harmful to their hosts in this way. The cause of death in acute as well as in more chronic cases of trichostrongylosis is not known, but it may be a toxin produced by the worms*. It has been estimated that about 2,000 worms are necessary to produce marked symptoms in a year-old sheep.

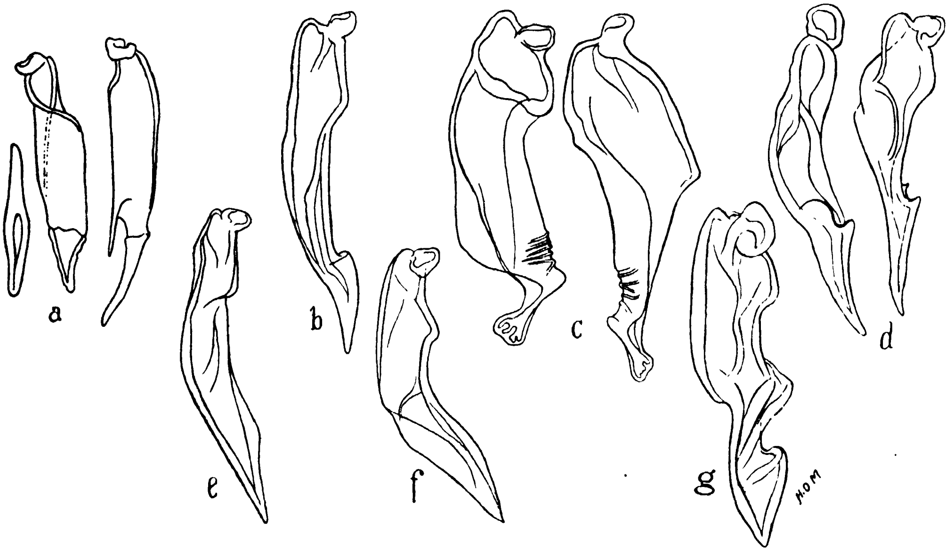

FIG. 121.—SPICULES OF SOME SPECIES OF *Trichostrongylus*. (ORIGINAL.)

a, Spicules and gubernaculum of *T. axei*; spicules of *b*, *T. colubriformis*; *c*, *T. rugatus*; *d*, *T. falculatus*; *e*, *T. vitrinus*; *f*, *T. capricola*; *g*, *T. probolurus*. (All drawn to same scale; both spicules shown only where they are unequal and dissimilar.)

Symptoms.—*T. axei* is only mildly pathogenic. In horses heavy infections may cause symptoms of gastric disturbance, but in such cases other worms are invariably also present in the alimentary canal and only the result of the total infection is seen. Cattle rarely suffer from *Trichostrongylus*. In the case of sheep and goats especially young animals are susceptible, and usually even these cannot be infected when they are in good condition unless an excessively large number is given. In South Africa trichostrongylosis is a disease of Persian sheep especially, merinos being much less susceptible. When a severe infection is acquired within a short time the disease may be acute and rapidly lead to death. Such animals usually show neither emaciation nor anæmia, but become weak in the legs, and are unable to stand shortly before they die. In more chronic cases the appetite is variable, emaciation occurs, the skin becomes dry, and there may be alternating constipation and diarrhœa; if anæmia is noticeable, it is mild. In Australia the parasites cause serious losses in young merino sheep which pass dark, diarrhœic fæces, hence the worm is popularly known as the " black scours worm."

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* See also Andrews, Kauffman and Davis, *Amer. Journ. Vet. Res.*, 5 (14): 22-29. 1944.

Post-Mortem.—In acute cases the carcass shows no other lesions than those in the intestine. The mucosa of this organ is swollen, especially in the duodenum, sometimes slightly hæmorrhagic, and it may be covered with mucus. The worms can be found by scraping the mucosa into a glass dish of water or by smearing scrapings over a glass plate, which is held up to the light.

In chronic cases the carcass is emaciated and the liver may show fatty changes. The lesions in the intestine are as described above. In the duodenum the submucous glands are greatly enlarged.

Diagnosis must be confirmed by making fæces cultures and identifying the infective larvæ.

Treatment. — Tetrachlorethylene, administered as described under *Bunostomum trigonocephalum*, as well as phenothiazine (p. 171), are very effective. The mixture of copper sulphate and nicotine recommended for tapeworms in sheep (p. 98) gives fairly good results. The treatment of heavily infected animals with certain drugs is dangerous because the desquamation produced by the parasites apparently allows rapid absorption of the drug. Arsenical drugs and remedies containing arsenic are for this reason strongly contra-indicated, and large doses of other drugs, possibly also carbon tetrachloride, may cause poisoning.

Prophylaxis.—The general preventive measures described on p. 180 should be applied. Since the final stage in the egg is very resistant, infected pastures are not easily sterilised. The most important prophylactic measures are the removal of other harmful worms by regular treatment and good feeding.

T. tenuis (Mehlis, 1846) occurs in Europe, Asia and North America in the cæca and small intestine of domestic and wild ducks and geese, fowl, guinea-fowl, turkey, pheasant and partridge. Male 5-6·5 mm., female 7·3-9 mm. long. The spicules are 0·13-0·15 mm. long and curved.

Life-Cycle.—The eggs are passed in the fæces of the host, and, under favourable conditions, the larvæ develop to the infective stage as in other strongyles. The worms mature in the birds in 7 days after infection.

Pathogenicity.—Severe infections may cause a hæmorrhagic typhlitis with diarrhœa. Later the birds suffer from loss of appetite, emaciation, anæmia, and toxæmia which may be due to the destruction of the cæcal mucosa and decomposition of the cæcal contents.

T. retortæformis (Zeder, 1800) occurs in the small intestine, rarely the stomach, of the rabbit, hare and goat. Male 5-7 mm., female 6-9 mm. long. The spicules are 0·12-0·14 mm. long. The eggs measure 85-91 by 46-56 μ.

Life-Cycle.—Direct.

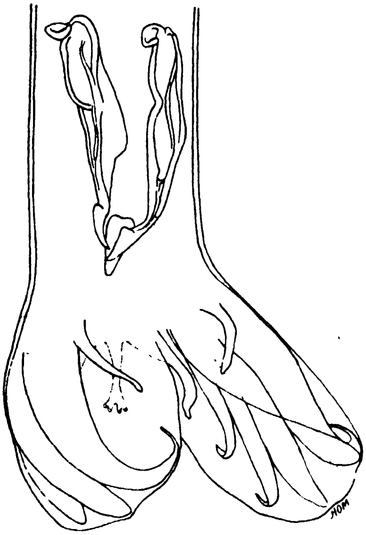

FIG. 122.—*Trichostrongylus retortæformis*, HIND END OF MALE, VENTRAL VIEW. (ORIGINAL.)

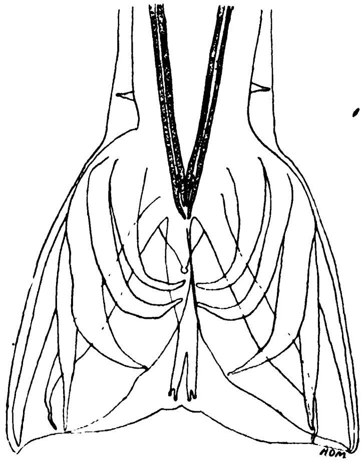

FIG. 123. — *Graphidium strigosum*, HIND END OF MALE, VENTRAL VIEW. (ORIGINAL.)

Pathogenicity.—The parasites penetrate into the mucosa, causing desquamation, and in heavy infections an inflammation with much mucus exudate may be seen. The affected animals suffer from anæmia and may die.

Control.—No effective drug is known. The runs should be kept dry and the fæces removed at short intervals.

Genus **Graphidium** Railliet and Henry, 1909

G. strigosum (Dujardin, 1845) occurs in the stomach and small intestine of the rabbit and hare in Europe. Male 8-16 mm., female 11-20 mm. long. The body cuticle bears 40-60 longitudinal ridges. The male bursa has large lateral lobes and a small dorsal lobe. The spicules are 1·1-2·4 mm. long, slender, and each ends distally in several points.

The vulva opens 1·14-3·28 mm. from the posterior extremity. The eggs measure 98-106 by 50-58 μ.

Life-Cycle.—Direct.

Pathogenicity and Symptoms.—The worms penetrate deeply into the wall of the stomach or intestine. In some cases no symptoms are seen even with severe infections, while in other cases anæmia, cachexia and even death may result.

Control.—No satisfactory anthelmintic is known. For prophylaxis hygienic measures are indicated, such as frequent removal of fæces and dryness of quarters.

Genus Hyostrongylus Hall, 1921

H. rubidus (Hassall and Stiles, 1892) occurs in the stomach of the pig in many countries. Male 4-7 mm., female 5-10 mm. long. The worms are slender and are of a reddish colour when fresh. The body cuticle is transversely striated and also bears 40-45 longitudinal striations. The bursa is well developed, but the dorsal lobe is small. The spicules are 0·13 mm. long. There is a narrow gubernaculum and a well-developed telamon. The vulva is situated 1·3-1·7 mm. anterior to the anus. The eggs measure 45 by 36 μ.

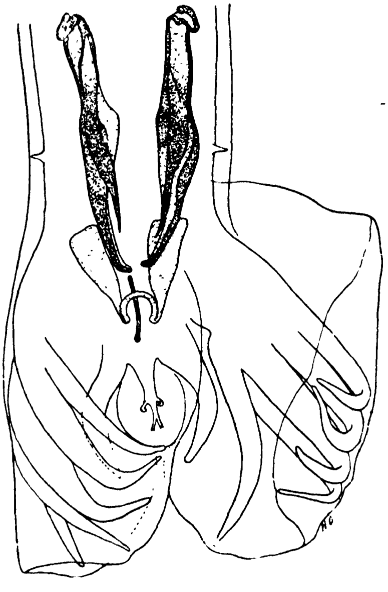

FIG. 124.—*Hyostrongylus rubidus*, HIND END OF MALE, VENTRAL VIEW. (ORIGINAL.)

Life-Cycle.—The eggs hatch, at ordinary temperatures, in 39 hours and the larvæ develop to the infective stage in 7 days. They are not very resistant to drying or low temperatures. Infection occurs per os and not through the skin. The worms reach maturity in 17-19 days.

Pathogenicity and Symptoms. — The parasites burrow into the gastric mucosa and suck blood. They appear to be comparatively harmless in the absence of other factors that would affect the general health of the host or the gastric mucosa in particular. They may be found in apparently healthy pigs without causing any ill effects, but if the resistance of the animal is lowered, marked lesions and symptoms may be produced, as Castle has, for instance, described in lactating sows. The animals lose condition rapidly and become weak, showing inco-ordination and a tendency to lie down frequently. The appetite may vary, but the animals are usually thirsty. Diarrhœa occurs and the fæces may be dark in colour.

Post-Mortem.—The degree of emaciation of the carcass depends on the severity of the case. The main lesions are found in the stomach, varying from hyperæmia and a catarrh in mild cases to a croupous gastritis. In the latter case the mucosa is thickened and shows areas covered with yellow, corrugated pseudo-membranes. The worms are found in these membranes as well as in the mucosa.

Diagnosis.—Until more details are known about the eggs and the larvæ of the parasites of the pig a tentative diagnosis can be made by finding the eggs of the worm in the fæces, but it can be definitely confirmed only by autopsy of a selected case.

Treatment.—Bozicevich and Wright obtained satisfactory results by giving carbon bisulphide in capsule or by stomach tube at the rate of 0·2 c.c. per kilo (8-10 c.c. per 100 lbs.) after starving for 36 hours (water allowed) and taking care that the fæces passed are not eaten.

Prophylaxis.—Hygienic measures, particularly frequent removal of fæces from sties and effective drainage in the runs or paddocks, are indicated.

Genus **Ornithostrongylus** Travassos, 1914

O. quadriradiatus (Stevenson, 1904) occurs in the crop, proventriculus and small intestine of the pigeon in North America, South Africa and Australia. Male 9-12 mm., female 18-24 mm. long. The worms are red in colour when fresh. The cuticle of the head is slightly inflated and the body cuticle has a number of longitudinal striations. In the male bursa the ventral rays are close together and the dorsal is fairly

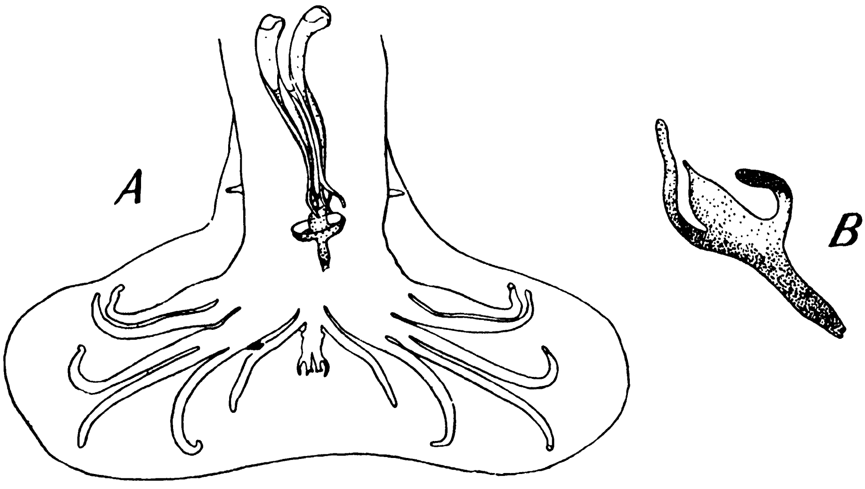

FIG. 125.—*Ornithostrongylus quadriradiatus.* (FROM BAYLIS, AFTER STEVENSON.) *A*, bursa, ventral view; B, " telamon," ventral view.

short. The spicules are 0·15-0·16 mm. long, each ending in three pointed processes. A telamon is present; it is roughly cross-shaped, the two arms forming an incomplete ring through which the spicules pass. The vulva opens about 5 mm. from the posterior extremity. The eggs measure 70-75 by 38-40 μ.

Life-Cycle.—Direct, like that of other Trichostrongylidæ.

Pathogenicity and Symptoms.—The worms burrow into the intestinal mucosa and severe infections cause a catarrhal enteritis, which results in a debilitating diarrhœa and interference with the normal functions of the intestine. The worms, moreover, are blood-suckers. The affected birds become anæmic, emaciated and weak, and may die.

Treatment unknown.

Prophylaxis.—General hygienic measures are indicated.

Genus **Libyostrongylus** Lane, 1923

L. douglassii (Cobbold, 1882) occurs in the proventriculus of the ostrich in South Africa. Male about 4-6 mm., female 5-6 mm. long. The colour of fresh specimens is yellowish-red. The male bursa is well developed and the dorsal ray is long and cleft in its distal half, forming three small branches on either side. The spicules are 0·14-0·158 mm. long, each ending in a large and a small spine. The vulva opens 0·8 mm. from the posterior extremity. The eggs measure 59-74 by 36-44 μ.

Life-Cycle.—The eggs are passed in the fæces of the host and the development and bionomics* of the free-living stages resemble those of *Strongylus equinus* (p. 164). The infective larval stage is reached under optimal conditions in 60 hours. The infective larva is about 0·745 mm. long, including the sheath, and morphologically bears a close resemblance to the larvæ of *Trichostrongylus* spp. Eggs containing fully formed embryos can resist desiccation as long as 3 years, and the infective larvæ remain viable under dry conditions for

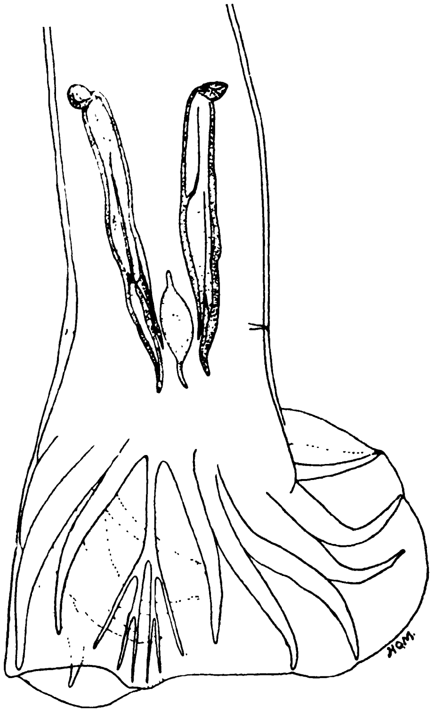

FIG. 126. — *Ornithostrongylus douglasii*, HIND END OF MALE, DORSAL VIEW. (ORIGINAL.)

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* Theiler and Robertson, *3rd and 4th Rep. Dir. Vet. Res.*, *Union of South Africa*, pp. 293-345. 1916.

9 months or longer. Infection of the host occurs per os. The worms develop to maturity in the ostrich in about 33 days, the first eggs being passed in the fæces on the thirty-sixth day.

Pathogenesis.—The young parasites penetrate deeply into the lumina of the glands in the proventriculus. The adults live in the surface epithelium of the organ, sucking blood and causing severe irritation.

Symptoms.—Chicks are most susceptible to infection, and adult birds, although susceptible, suffer much less from the parasite, especially when they are well fed. The birds become anæmic, weak, emaciated and stunted in growth. Severe losses of chicks may be experienced.

Post-Mortem.—Apart from emaciation and anæmia the characteristic lesions are found in the proventriculus. The mucosa is swollen and covered with an excessive amount of tough mucus. The mucosa is desquamated in patches and pseudo-membranes may be present, covering hæmorrhagic areas. The worms are found in and underneath the mucus and the pseudo-membranes.

Diagnosis.—The symptoms would lead to a tentative diagnosis, which must be confirmed by finding the infective larvæ in fæces cultures or by autopsy of a selected bird. The eggs cannot be differentiated from those of *Codiostomum struthionis*, and the infective larvæ of the latter species have not been described, but they do not resemble the larvæ of *O. douglasii.*

Treatment is a difficult matter on account of the location of the parasites. The drugs tested by Theiler and Robertson gave no satisfactory results. Carbon tetrachloride, to which ostriches are fairly resistant, should be tried.

Prophylaxis.—Since birds and runs may remain infected for long periods, the chicks should be kept away from the adult birds in clean runs and fed with crops grown on clean lands. If hens and chicks are kept together, the droppings of the adult birds should be removed every 24-48 hours. Infected adult birds suffer little from the effect of the parasites when they are well fed.

Genus **Ostertagia** Ransom, 1907

The species of this genus, which occur in the abomasum and rarely the small intestine of sheep, goats, cattle and other ruminants, are usually known as " brown stomach-worms " on account of their colour when fresh. The worms are slender. The cuticle of the anterior extremity may be slightly inflated, transversely striated, and the " head " is not more than 0·025 mm. wide. The rest of the body cuticle bears 25-35 longitudinal ridges and has no transverse striations. The male bursa has lateral and dorsal lobes and an accessory bursal membrane situated anteriorly on the dorsal side. The spicules are pigmented brown, relatively short, and end posteriorly in two or three processes. The vulva of the female may be covered by a small anterior flap.

O. ostertagi (Stiles, 1892) occurs in the abomasum of cattle and sheep, rarely the horse. Male 6·5-7·5 mm., female 8·3-9·2 mm. long. The spicules are 0·22-0·23 mm. long, and each ends in three bluntly hooked processes. The vulva opens in the posterior fifth of the body and is covered by a flap. The eggs measure 80-85 by 40-45 μ.

O. circumcincta (Stadelmann, 1894) occurs in the abomasum of sheep and goats. Male 7·5-8·5 mm., female 9·8-12·2 mm. long. The spicules are slender, 0·28-0·32 mm. long. Each ends in a large knobbed and a small, acute process. The vulva is usually covered by a flap, and opens in the last fifth of the body. The eggs measure 80-100 by 40-50 μ. Near the tip of the female tail there is a thickened band which bears 4-5 transverse striations. A similar band is also seen in some other species of this genus.

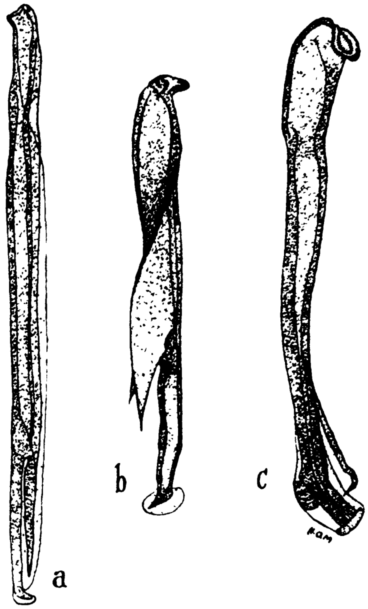

FIG. 127.—SPICULES OF COMMON *Ostertagia* SPECIES. (ORIGINAL.)

a, *O. circumcincta* ; *b*, *O. trifurcata* ; *c*, *O. ostertagi*. (All same magnification.)

O. trifurcata Ransom, 1907, occurs in the abomasum of sheep and goats. Male 6·5-7 mm. long. The spicules are about 0·18 mm. long and each ends in a stout, knobbed tip, while just behind the middle two sharp spurs are given off medially.

Several other species have been described from domestic ruminants in various countries.

Life-Cycle.—Direct and similar to that of other Trichostrongyles.* Infection of the host occurs per os. For measurements of infective larvæ, see p. 181.

Pathogenesis, Symptoms and Lesions.—When the infective larvæ of *O. ostertagi* are ingested by the host they penetrate into the mucosa of the abomasum, causing the formation of small, circular, raised areas about 1-2 mm. in diameter. In these nodular lesions the worms develop and the adults may also be found in them, partly projecting through a small opening in the centre, or they may live free on the mucosa. The small nodular lesions should be differentiated from those produced by protozoa of the genus *Globidium*. The other species are found chiefly in the fundus portion of the abomasum, lying in a tough mucus which covers the mucosa, or partly embedded in the latter, which is markedly œdematous in severe cases. They can usually be seen with the naked eye on account of their dark colour. The worms suck blood, and heavy infections produce anæmia, cachexia, weakness and death. These worms appear to be particularly pathogenic to angora goats and certain breeds of sheep, while cattle may also be severely affected.

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* See Threlkeld, *Virginia Agr. Exp Sta. Techn. Bull. No.* 52. 1934.

Treatment.—Although these parasites occur in the abomasum like *Hæmonchus*, they are much more difficult to kill by means of drugs. Tetrachlorethylene and phenothiazine are indicated.

Prophylaxis.—The general measures described on p. 180 should be applied. Poorly-fed and young animals are more susceptible than others. Under ordinary conditions animals that are kept free of other harmful parasites will not become badly infected by *Ostertagia* unless they run on heavily infected pasture.

Genus **Marshallagia** Orloff, 1933

This genus is closely allied to *Ostertagia* in its morphology, hosts and habits. The eggs are large, like those of *Nematodirus*, but contain a morula stage when passed in the fæces of the host (see egg plate of sheep worms, p. 19).

Genus **Cooperia** Ransom, 1907

The *Cooperia* species, which are usually found in the small intestine, rarely the abomasum, of ruminants, are relatively small worms, of a reddish colour when fresh. The cuticle of the anterior extremity frequently forms a cephalic swelling, and the rest of the body cuticle bears 14-16 longitudinal ridges which are transversely striated. The male bursa has a small dorsal lobe. The latero-ventral ray is thicker than the ventro-ventral and divergent from it, but its tip again approaches the latter. The postero-lateral is slender and the externo-dorsal usually arises from the base of the dorsal stem. The spicules are stout, relatively short, pigmented brown, and usually have a ridged, wing-like expansion at the middle. An accessory piece is absent. The vulva may be covered by a flap and is situated behind the middle of the body.

C. curticei (Railliet, 1893) occurs in sheep and goats. Male 4·5-5·4 mm., female 5·8-6·2 mm. long. Spicules 0·135-0·145 mm. long.

C. punctata (v. Linstow, 1907) occurs in cattle and rarely in sheep. Male 4·7-5·9 mm., female 5·7-7·5 mm. long. Spicules 0·12-0·15 mm. long.

C. pectinata Ransom, 1907, occurs in cattle and rarely in sheep. Male 7 mm., female 7·5-9 mm. long. Spicules 0·24-0·28 mm. long.

C. oncophora (Railliet, 1898) occurs in cattle and sheep and rarely the horse. Male 5·5-9 mm., female 6-8 mm. long. Spicules 0·24-0·3 mm. long. Several other species are known from domestic and wild ruminants, and some which occur in the latter have been transmitted to sheep experimentally.

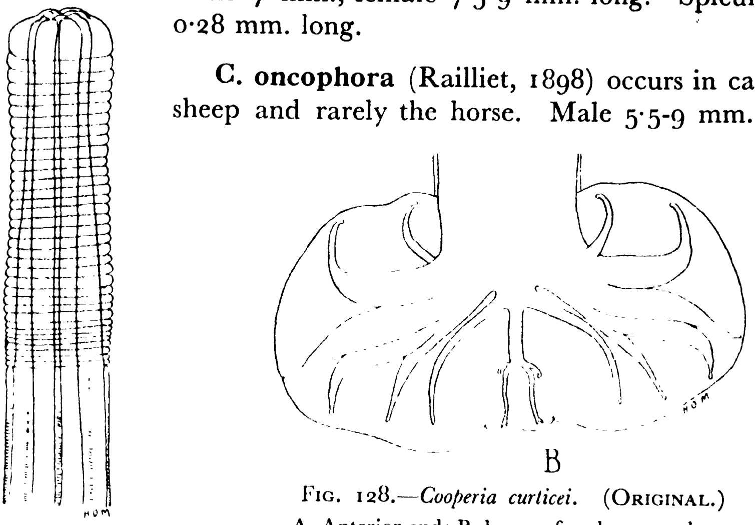

FIG. 128.—*Cooperia curticei.* (ORIGINAL.)
A, Anterior end; B, bursa of male, opened out.

Life-Cycle.—Direct and in general similar to that of *Strongylus equinus* (p. 164). Infection of the host occurs per os. The infective larva has a pointed tail and is surrounded by a sheath with a medium-sized tail. For measurements, see p. 181.

Pathogenicity, Symptoms and Lesions.—The worms penetrate into the mucosa of the small intestine and suck blood. A light infection is of no consequence, but young cattle and sheep may be severely affected by heavy infections, which are usually acquired on wet pastures. The symptoms and lesions are similar to those of trichostrongylosis, but anæmia is more marked.

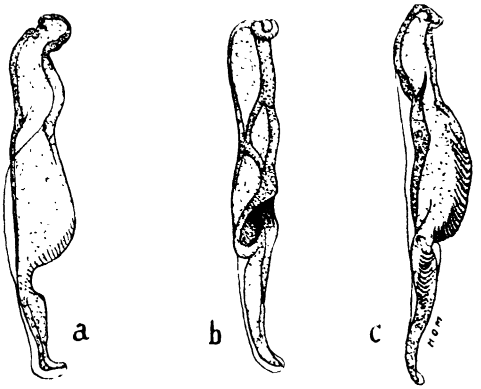

FIG. 129.—SPICULES OF COMMON *Cooperia* SPECIES. (ORIGINAL.)
a, C. curticei ; b, C. punctata ; c, C. pectinata. (Not drawn to same scale.)

Diagnosis has to be made by fæces culture and the identification of the infective larvæ, since the eggs of the *Cooperia* species cannot be identified in the fæces.

Treatment and Prophylaxis.—Phenothiazine (p. 171) or tetrachlorethylene is indicated. The general prophylactic measures described on p. 180 will do much to control the infection.

Genus **Nematodirus** Ransom, 1907

The species of this genus are relatively long worms with a filiform anterior portion. They have an inflated cuticle around the anterior end and about 14-18 longitudinal ridges on the body cuticle. The male bursa has fairly large lateral lobes, while the dorsal lobe with its supporting rays is split in two and each half is attached to a lateral lobe. The spicules are long and slender and their tips are fused together. The tail of the female is short and truncate, with a slender terminal appendage. The vulva opens at the posterior third of the body. The eggs are large and contain about eight cells when passed in the fæces of the host. About eight species are known from domestic ruminants.

N. spathiger (Railliet, 1896), frequently confused with *N. filicollis* (Rudolphi, 1802), is the commonest species and occurs in the small intestine of sheep, cattle and other ruminants. Male 10-15 mm., female 15-23 mm. long. Spicules 0·7-1·21 mm. long, terminating together in a spoon-shaped expansion. The eggs measure 150-230 by 80-110 μ and contain an embryo of about eight cells when passed by the host.

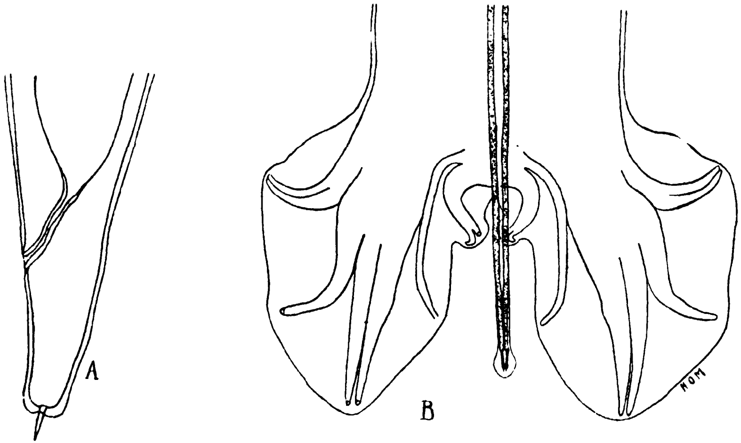

FIG. 130.—*Nematodirus spathiger.* (ORIGINAL.)
A, Hind end of female; B, hind end of male, bursa opened out.

Life-Cycle.—The eggs develop under suitable conditions (p. 164), but the larva hatches only when the infective stage has been reached after two ecdyses. The embryos in the eggs are killed by freezing and desiccation. When the infective larva leaves the egg-shell it is enclosed in the cuticle of the second stage, which has a very long tail (for measurements, see p. 181). The tail of the larva itself ends in a dorsal and a ventral lobe, as if a wedge had been cut out between them, and in this notch arises a backwardly projecting finger-like appendage. The infective larvæ are very resistant to desiccation and freezing, and show a strong negative geotropism. Infection of the host occurs per os and the larvæ develop to maturity in the intestine in 29 days.

Pathogenicity and Symptoms.—The pathogenicity of these worms depends on their numbers and on the resistance of the host. Well-fed lambs are able to harbour large infections without showing any symptoms. In other cases heavy infections may cause symptoms like those of trichostrongylosis. In South Africa the distribution of *N. spathiger* is restricted to the dry Karroo area, where the soil is gravelly, and the parasite reduces the resistance of sheep to other worm infections.

Treatment.—Tetrachlorethylene, as administered against hookworms, is effective. Phenothiazine is rather ineffective.

Prophylaxis.—See p. 180.

Genus **Hæmonchus** Cobb, 1898

H. contortus (Rudolphi, 1803) occurs in the abomasum of sheep, goats, cattle and numerous other ruminants in most parts of the world. It is commonly known as the "stomach-worm" or "wireworm" of ruminants, and is one of their most pathogenic parasites. Male 10-20 mm., female 18-30 mm. long. The male has an even reddish colour, while in the female the white ovaries are spirally wound around the red intestine, producing the appearance of a barber's pole. The cuticle is in parts transversely striated and also bears a number of longitudinal ridges. The cervical papillæ are prominent and spine-like. A small buccal cavity is present, containing a dorsal lancet. The male bursa has elongate lateral lobes supported by long, slender rays, while the small dorsal lobe is asymmetrically situated against the left lateral lobe and supported by a Y-shaped dorsal ray. The spicules are 0·46-0·506 mm. long, each provided with a small barb near its extremity. The vulva of the female is covered by an anterior flap, which is usually large and very prominent, but may be reduced to a small knob-like structure in some specimens. The eggs measure 70-85 by 41-48 μ, and contain an embryo of 16-32 cells when passed in the fæces of the host.

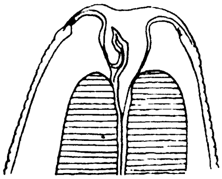

FIG. 131.—*Hæmonchus contortus*, ANTERIOR END, LATERAL VIEW.

Several other species of this genus are known from domestic and wild ruminants and can be recognised mainly by the spicules of the males.

Life-Cycle.—In general the development and bionomics of the free-living stages are similar to those of *Strongylus equinus* (p. 164). The eggs hatch under suitable conditions and the infective stage is reached in about 4 days. The pre-infective stages cannot resist desiccation, but withstand freezing for prolonged periods. The infective larva is sheathed and the sheath has a moderately long tail (for measurements, see p. 181). It is an active climber and is strongly resistant to desiccation and freezing. Infection of the host occurs per os, and the worms grow to maturity in the abomasum in about 18 days. The first eggs are usually passed in the fæces of the host about 18-21 days after infection.

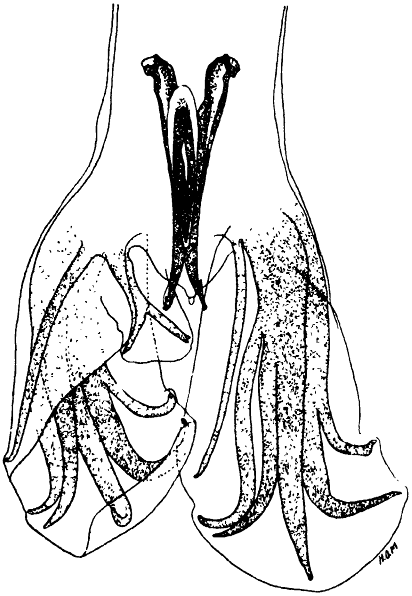

FIG. 132.—*Hæmonchus contortus*, HIND END OF MALE, DORSAL VIEW. (ORIGINAL.)

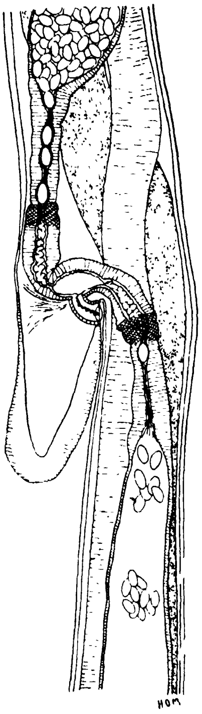

FIG. 133.—*Hæmonchus contortus*, VULVAR REGION OF FEMALE. (ORIGINAL.)

Pathogenesis.—When the young worms enter the host they cast the sheath and burrow into the mucosa of the abomasum, where the third ecdysis occurs. The fourth-stage larva begins to suck blood and causes the formation of a small blood clot on the mucosa, underneath which it lies. The adult worms live free in the abomasum and attack the mucosa, which they pierce with their buccal lancets to suck blood. Probably an anticoagulatory substance is injected into the wound by the parasite.

The mucosa is therefore strongly irritated and the worms deprive the host of a large quantity of blood. It is very probable that *Hæmonchus* acts in a similar way as *Ancylostoma caninum* by passing a large amount of blood through its body, since the abomasal contents usually show a conspicuous admixture of blood pigments in heavy infections. Stewart found that *Hæmonchus* infection causes a depression of the digestibility and absorption of protein, calcium and phosphorus.

Symptoms.—In acute cases—that is, when lambs or young sheep, which are the most susceptible, acquire a sudden, severe infection—anæmia develops rapidly and the animals die without showing much more than symptoms of anæmia and hydræmia. In more chronic cases anæmia is also the main symptom, and œdematous swellings are frequently seen under the jaw and sometimes along the ventral aspect of the abdomen. The animals become progressively weak and later walk with a swaying gait. Emaciation is as a rule not seen in pure hæmonchosis because the body fat is replaced by a gelatinous tissue. The skin becomes pale, and in sheep the wool falls out in patches. Occasionally diarrhœa or constipation may occur and the appetite is variable. Shortly before death great weakness may lead to prostration. The blood shows a marked decrease of erythrocytes and the presence of various abnormal and primitive blood cells. The parasites cause no hæmolysis and there is no evidence of a direct action on the blood-forming organs according to Fourie,* the changes which occur in these organs being due to exhaustion as a result of the excessive drain on the blood caused by the parasite.

Post-Mortem.—The mucous membranes and the skin are pale, while the blood has a watery appearance. The internal organs are also markedly pale. Hydrothorax, hydropericard and ascites are usually conspicuous and an extreme cachexia is present, the fat being replaced by a gelatinous tissue. The liver has a light-brown colour, it is fragile and shows fatty changes. The abomasum contains reddish-brown, fluid ingesta, frequently a fair amount of sand and the parasites, which swim about actively if the carcass is still warm. The mucosa is swollen and covered with small red bite-marks of the parasites. Occasionally shallow ulcers with ragged edges are found, and a number of the worms may be firmly attached with their anterior extremities in these ulcers. The intestine may contain a few worms which were being passed out by the host.

Diagnosis.—The symptoms alone may lead to a suspicion of hæmonchosis, but a definite diagnosis can only be made by autopsy of selected cases or by fæces culture and the identification of the infective larvæ (p. 181).

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* *17th Rep. Dir. Vet. Serv. and Anim. Ind., South Africa*, pp. 495-572. 1931.

Treatment.—Phenothiazine is very effective against this parasite and doses of 5 gm. are sufficient for sheep. On account of the great resistance of infective larvæ in the pasture, however, regular treatments are necessary, and for this purpose phenothiazine is usually too expensive. The drug can be used as described under *Œsophagostomum* at certain seasons, but at other times cheaper drugs can be given.

Copper sulphate, with or without nicotine or arsenic, is generally employed. A 1 per cent. solution of copper sulphate is administered to sheep, especially in the United States, at the rate of 100 c.c. for yearlings and older sheep, and 50 c.c. for lambs 3-12 months old. A short length of rubber tubing with a funnel at one end and a metal tube at the other, which is placed in the sheep's mouth, is used for administration. For dosing larger numbers of sheep, other suitable devices have been made.

The mixture of copper sulphate and nicotine employed against tapeworms in sheep (p. 98) is also effective against *Hæmonchus* and is recommended especially for cattle. The Nodular Worm Remedy employed in South Africa (p. 179) is effective against *Hæmonchus*. Tetrachlorethylene is quite suitable, but carbon tetrachloride is not sufficiently effective in safe doses.

Preliminary starvation for 12-18 hours before dosing is often practised but appears to be unnecessary. Extensive practical tests have shown that as good results are obtained without starvation. The importance of continuous treatment at regular intervals cannot be overstressed. On heavily infected pasture, animals in good condition could be treated every fortnight, but ordinarily intervals of 3 weeks are adequate in order to kill off the worms before they reach the egg-laying stage. It has been found that the young stages of the parasite in the abomasum are not easily killed before the fourth ecdysis has been completed. It is therefore possible that eggs may be passed by the host even as soon as 14 days after treatment.

Prophylaxis.—The general measures described on p. 180 are of the utmost importance. Control of *Hæmonchus* means to a great extent control of other nematode parasites of sheep. This worm is the most pathogenic and, by reducing the general condition and resistance of the host, it allows other species to establish an infection which the host could normally have resisted. Regular treatment is therefore mainly prophylactic in nature, since it prevents further increase of the *Hæmonchus* infection in the pasture and maintains the natural resistance of the animal.

Genus **Mecistocirrus** Railliet and Henry, 1912

M. digitatus (von Linstow, 1906) occurs in the abomasum of sheep, cattle, zebu, buffalo and the stomach of the pig and rarely man in eastern countries and in Central America. Male up to 31 mm., female up to 43 mm. long. The cuticle bears about 30 longitudinal ridges. The cervical papillæ are prominent and the small buccal capsule contains a lancet as in *Hæmonchus*. The female resembles that of the latter species in having the ovaries wound spirally around the intestine. The male bursa has a small, symmetrical dorsal lobe; the ventro-ventral ray is small, while the latero-ventral and antero-lateral rays are conspicuously longer than the other rays. The spicules are slender, 3·8-7 mm. long, and united together for almost their whole length. The vulva of the female opens near the anus and the vagina is long. The eggs measure 95-120 by 56-60 μ.

Life-Cycle.—Probably direct.

Pathogenicity, etc.—Very similar to *Hæmonchus*.

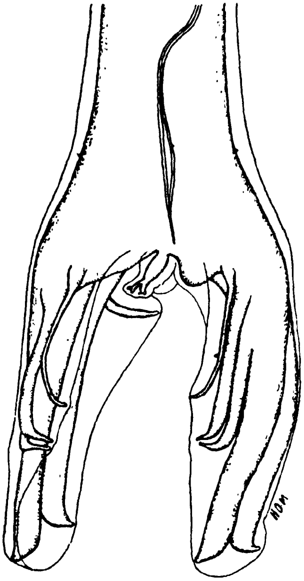

FIG. 134.—*Mecistocirrus digitatus*, HIND END OF MALE, DORSAL VIEW. (ORIGINAL.)

Genus **Ollulanus** Leuckart, 1865

O. tricuspis Leuckart, 1865, occurs in the stomach of the cat, fox, wild *Felidæ* and the pig. Male 0·7-0·8 mm., female 0·8-1 mm. long. A small buccal cavity is present. The male bursa is well developed, and the spicules, which are 0·046-0·057 mm. long and stout, are each split into two for a considerable distance. The tail of the female ends in three or more short cusps. The vulva is situated in the posterior part of the body, and there is only one uterus and ovary.

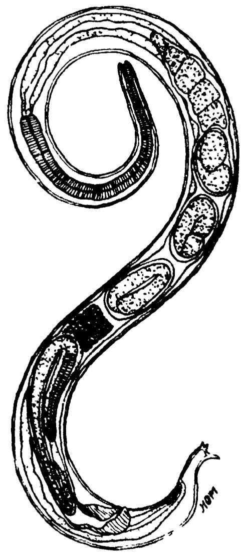

FIG. 135.—*Ollulanus tricuspis*, FEMALE. (ORIGINAL.)

Life-Cycle.—The worms are viviparous and the larvæ develop in the uterus of the female to the third larval stage. According to Cameron* the infection is spread through the vomit of an infected animal which is eaten by another susceptible one.

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* *Journ. Helm.*, 5 (2): 67-80. 1927.

Pathogenicity.—This parasite is considered to be comparatively harmless to cats, although the worms burrow into the gastric mucosa, causing slight erosions and increased secretion of mucus. Kotlán* ascribes a chronic catarrhal hypertrophic gastritis and emaciation to this parasite in the pig.

Treatment.—Unknown. Infected cats and pigs should be destroyed or isolated to prevent the infection from spreading.

Family METASTRONGYLIDÆ

Strongyloidea in which the buccal capsule is absent or vestigial and the rays of the male bursa are usually atypical, being reduced or partly fused together. The worms are parasitic in the air passages of the lungs or in the pulmonary bloodvessels of mammals and are commonly known as lungworms.

Genus **Dictyocaulus** Railliet and Henry, 1907

D. filaria (Rudolphi, 1809) occurs in the bronchi of sheep, goats and some wild ruminants. It has a world-wide distribution and causes serious losses. Male 3-8 cm., female 5-10 cm. long. The worms have a milk-white colour and the intestine shows as a dark line. There are four small lips and a very small, shallow buccal capsule. In the male bursa the medio- and postero-lateral rays are fused together except at their tips; the externo-dorsals arise separately and the dorsal ray is cleft right from its base. The spicules are stout, dark-brown, boot-shaped and 0·4-0·64 mm. long. The vulva is situated not far behind the middle of the body. The eggs measure 112-138 by 69-90 μ and contain fully formed larvæ when laid.

Life-Cycle.—The eggs may hatch in the lungs, but are usually coughed up and swallowed, and hatch while they pass through the alimentary tract of the host. Some eggs may be expelled in the nasal discharge or sputum. The first-stage larva passed in the fæces is 0·55-0·58 mm. long and can be easily recognised by the presence of a small cuticular knob at the anterior extremity and numerous brownish food granules in the intestinal cells. The free stages do not feed, but exist on these food granules. After 1-2 days the larva reaches the second stage, but does not cast the old cuticle until the third or infective stage is reached, so that the latter is for some time enclosed in two sheaths. The first is then cast while the second is retained for protection. The larvæ require moisture for their development and, at a temperature of about 27° C., reach the infective stage in 6-7 days. The infective larvæ are not very active and have a weak negative geotropism. They can withstand moderately dry conditions for a few days, but are able to live in moist conditions for several months and are fairly resistant to low temperatures. Infection of the host occurs per os. The larvæ penetrate into the intestinal wall within 3 days and pass via the lymph vessels to the mesenteric lymph glands, where they develop and perform the third ecdysis about 4 days after infection, as was found by Hobmaier. In the fourth stage males and females can be distinguished. The worms now pass via the lymph and bloodvessels to the lungs, where they are arrested in the capillaries and break through into the air passages. Some larvæ may pass through the pulmonary capillaries into the systemic circulation and set up a prenatal infection in a fœtus. Development to maturity in the host takes about 6 weeks.

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* *Deut. Tierärztl. Wschr.*, 41 (44): 689-692. 1933.

Pathogenesis.—The worms live in the small bronchi, where they suck blood and irritate the mucosa, producing a catarrhal bronchitis. The inflammatory process spreads to the surrounding peribronchial tissues and the exudate frequently passes back into the bronchioles and alveoli, causing atelectasis and catarrh, or pneumonia may be set up by bacteria which invade the affected tissues. The young larvæ passing through the intestine may irritate the mucosa and cause diarrhœa.

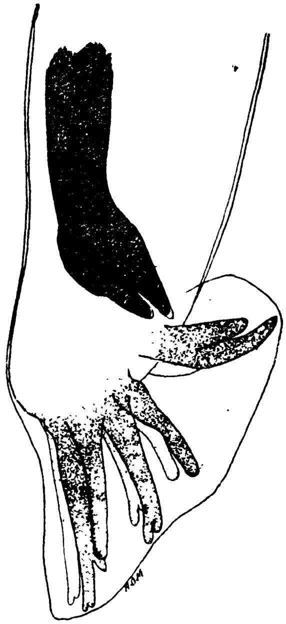

FIG. 136.—*Dictyocaulus filaria*, HIND END OF MALE, LATERAL VIEW. (ORIGINAL.)

Symptoms.—Young animals are chiefly affected, but the disease may occur at all ages and is usually chronic. The animals cough and a tenacious mucus exudes from the nostrils. Dyspnœa is usually obvious, the respiration is more rapid than normal and abnormal lung sounds can be heard on auscultation. Emaciation and anæmia are marked and œdemas may be seen. Diarrhœa is not infrequent. The temperature is not elevated unless pneumonia develops.

Post-Mortem.—The carcass is emaciated and anæmic. The lungs show atelectatic areas of variable size. The bronchi in the affected parts contain the worms and a large amount of mucus which is mixed with blood, and is slightly opaque on account of the presence of desquamated epithelial cells, leucocytes and the eggs of the worms. The bronchial mucosa and the peribronchial tissues are inflamed and infiltrated with leucocytes. Localised and often cone-shaped areas of pneumonia, accompanied by atelectasis and compensatory emphysema, may be present. In some cases proliferation of the bronchial epithelium has occurred.

Diagnosis is made by finding the larvæ in the fresh fæces (for technique, see pp. 16-18). Eggs may be found in the sputum or nasal discharge, but their absence is not significant.

Treatment.—Many methods of treatment have been recommended, but they are not effective. Orloff* states that the sheep must be placed on its back in a trough-like receptacle, raised at the head end, so that the fluid injected will flow into the dorsal parts of the lungs where the parasites are mostly situated. He recommends two injections, on two successive days, of 10 c.c. of the following mixture: 1 c.c. 10 per cent. tincture of iodine, 50 c.c. glycerin and 150 c.c. distilled water. The injections are made with a short needle into the anterior third of the trachea, injecting backwards. After the injection the sheep is kept in a sitting position for 20-30 seconds. Velu and Zottner† recommend three 10 c.c. doses of an aqueous solution of pyrethrin containing 1 mgm. pyrethrin per dose. In this case the drug is administered through the nose by means

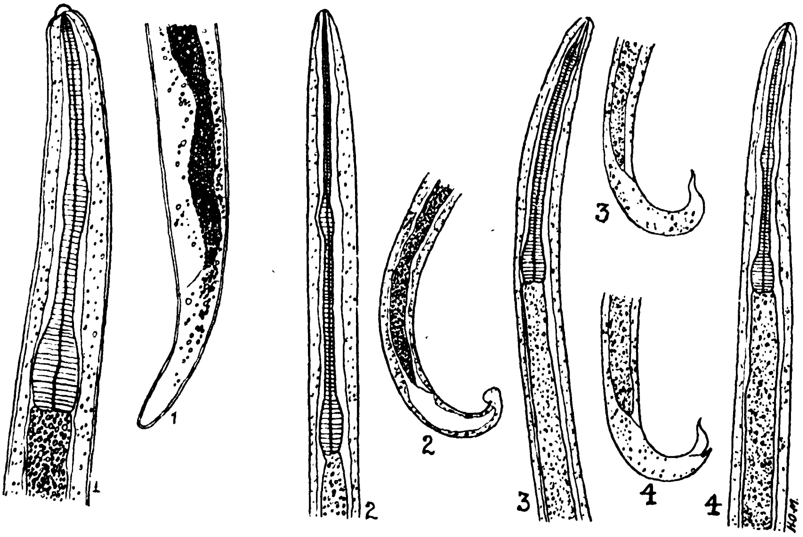

FIG. 137.—LARVAL STAGES OF LUNGWORMS AS FOUND IN FRESH FÆCES OF HOSTS. (ORIGINAL.)

Anterior and posterior ends of 1, *Dictyocaulus filaria*; 2, *Metastrongylus apri*; 3, *Protostrongylus rufescens*; 4, *Muellerius capillaris*.

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* *Bull. Acad. Vet. France*, 8 (7): 390-401. 1935. † *Ibid.*, 10 (1): 53-58. 1937.

of a rubber nozzle measuring 12-15 cm. by 4-5 mm., the sheep being kept in a sitting position and thereafter on its back for a few seconds.

If the animals are sheltered against adverse weather conditions and well fed, they soon lose their parasites, which do not live long in the host. This may account for many apparent successes in attempted treatment and is itself the best treatment that can be recommended.

Prophylaxis.—The animals must be removed from infected ground, placed on dry pastures and supplied with clean drinking water. Their fæces should not be used for fertilising lands on which crops for green feeding are grown. Moist pastures must be avoided, while dry pastures are fairly safe, because the infective larvæ are not very resistant to dryness. The general prophylactic measures described on p. 180 are also important. The larvæ rarely live through the winter in cold climates, and the infection is usually carried on by older animals, which show no symptoms. They should therefore not be grazed together with the young stock.

D. viviparus (Bloch, 1782) occurs in the bronchi of cattle and deer and has a cosmopolitan distribution. Male 4-5·5 cm., female 6-8 cm. long. The worm closely resembles the preceding species, but the medio- and postero-lateral rays are completely fused and the spicules are only 0·195-0·215 mm. long. The eggs measure 82-88 by 33-38 μ.

Life-Cycle.—Similar to that of *D. filaria.* The parasitic development is not known. The infective stage is reached in about 4 days. The first-stage larva found in the fresh fæces of the host is 0·3-0·36 mm. long and has no anterior knob, but the intestinal cells also contain numerous brownish granules.

Pathogenicity, Symptoms and Lesions.—Usually only calves are affected and the disease is similar to that produced by *D. filaria.* The animals have a characteristic spasmodic cough (" husk " or " hoose ") and suffer from dyspnœa. Emaciation, anæmia and diarrhœa are also observed. At autopsy pulmonary emphysema is commonly seen and secondary lobar pneumonia is not infrequent.

Treatment.—Since the worms are often located in the larger bronchi which are not blocked, intratracheal injections are somewhat more effective than in the case of sheep. Good feeding and shelter are, however, more important, and at the same time the animals should be protected against further infection. The following are some of the mixtures that have been recommended for intratracheal injection: (i.) 1 part tincture iodii and 10 parts benzol or glycerin, dose 2 c.c.; (ii.) turpentine 2 c.c., phenol 1 c.c. and chloroform 2 c.c.; (iii.) 1 part beechwood creosote in 10 parts glycerin, dose 2-4 c.c. In all cases the fluid must be injected slowly and during inhalation. The treatment must be repeated two to three times at intervals of about 3 days.

Prophylaxis.—As in the case of *D. filaria.*

D. arnfieldi (Cobbold, 1884) occurs in the bronchi of the horse, donkey and tapir and is found in most countries. Male up to 36 mm., female up to 60 mm. long. The medio- and postero-lateral rays of the male bursa are fused for about half their length. The spicules are 0·2-0·24 mm. long. The eggs measure 80-100 by 50-60 μ.

Life-Cycle.—Similar to that of *D. filaria,* but most eggs do not hatch before being passed in the fæces. According to Wetzel and Enigk the fourth-stage larvæ are found in the lung parenchyma during their passage from the lymph-vessels to the bronchi. The worms grow adult in 39 days after infection.

Pathogenicity.—As a rule this parasite is not very pathogenic, although some authors state that it is able to produce symptoms and lesions like other species of this genus. The donkey appears to be the most natural host of this parasite and may harbour a large number of the worms without showing appreciable symptoms. With regard to treatment, little is known. Symptomatic and prophylactic treatment should be applied as in other lungworm diseases.

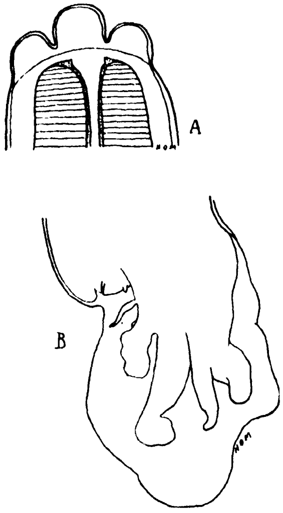

FIG. 138. — *Metastrongylus apri.* (ORIGINAL.)
A, Anterior end, lateral view; B, bursa of male, lateral view.

Genus **Metastrongylus** Molin, 1861

M. apri (Gmelin, 1790) (syn. *M. elongatus*) occurs in the bronchi and bronchioles of the pig, wild pigs, ruminants (?) and accidentally in man. Its distribution is cosmopolitan. Male up to 25 mm., female up to 58 mm. long. The worms are white and have six small lips or rather papillæ around the oral aperture. The male bursa is relatively small; the antero-lateral ray is large and has a swollen tip; the medio-lateral and postero-lateral are fused and the dorsal rays are much reduced. The spicules are filiform, 4-4·2 mm. long, and end in a single hook each. The posterior end of the female is flexed ventrad. The vulva opens near the anus and the vagina is 2 mm. long. The eggs measure 45-57 by 38-41 μ and contain a fully developed embryo when laid.

Life-Cycle.—The eggs are passed in the fæces of the host and may hatch soon thereafter or only after they have been swallowed by the intermediate host. The first-stage larva is 0·25-0·3 mm. long, the intestinal cells are filled with opaque granules, the hind end is strongly curved and the tip of the tail is bluntly rounded or swollen. The larvæ may live up to 3 months in moist surroundings, but are not infective and can proceed with their development only after they have been ingested by a suitable species of earthworm. The following species are concerned: *Lumbricus terrestris*, *L. rubellus*, *Diplocardia* sp., *Eisenia austriaca*, *Dendrobæna rubida*, *Helodrilus fœtidus*, and *H. caliginosus*. The larvæ develop in the walls of the œsophagus and proventriculus of the intermediate host and reach the infective stage in about 10 days, after performing two ecdyses and retaining the second skin as a sheath. They grow to about 0·52 mm., and when infective concentrate in the blood-vessels of the earthworm. The latter does not suffer from even very severe infections and the larvæ can pass the winter in the earthworm. They do not escape spontaneously from the intermediate host, but if the earthworm is hurt or dies, the liberated larvæ are able to live in moist soil for about 2 weeks. Pigs become infected by ingesting infected earthworms or accidentally liberated infective larvæ. In the pig the development is similar to that of *D. filaria* in the sheep, the larvæ passing through the mesenteric lymphatic glands, where they moult once and then reach the lungs, where they grow adult after a further moult. The first eggs are laid after about 24 days.

M. pudendotectus (Wostokow, 1905) (syn. *M. brevivaginatus*, *Chœrostrongylus pudendotectus*) also occurs in the pig in most parts of the world. Male 16-18 mm., female 19-37 mm. long. It differs from the preceding species mainly in having a larger bursa, spicules only 1·2-1·4 mm. long, and provided with double hooks, and the vagina 0·5 mm. long. The tail of the female is straight and a swelling covers the vulva and anus. The eggs measure 57-63 by 39-42 μ.

Life-Cycle.—Similar to that of *M. apri*.

M. salmi Gedoelst, 1923, occurs in the pig in the Belgian Congo, Indo-China and the United States. The spicules are 2-2·1 mm. long and the vagina of the female 1·6 mm.

Pathogenicity and Symptoms of Pig Lungworms.—In general as in the case of *D. filaria*, but the pig lungworms are not as pathogenic as those which occur in ruminants. In young pigs a verminous bronchitis and pneumonia may sometimes be seen, possibly due to a secondary bacterial infection. As a rule, however, the parasites cause mainly loss of condition and retarded growth, which is rather important in pigs. The parasites may sometimes die in the small bronchioles and give rise to the formation of nodules, which must be differentiated from tuberculous nodules at autopsy or at meat inspection.

Shope* found that the virus of swine influenza is carried by the larvæ of pig lungworms and persists in them, when they are carried by earthworms, for 32 months. Pigs infected with such larvæ acquire influenza from them.

Diagnosis is made by demonstrating the larvæ in the fresh fæces.

Treatment.—No suitable treatment is known except shelter and good feeding.

Prophylaxis.—Infected pigs should be kept on dry ground or in sties with concrete floors and their fæces should be disposed of in such a way that they do not spread the infection. Clean and young pigs should be run on clean fields, preferably where there are no earthworms. Infected paddocks and fields may remain infected for a considerable time, since the intermediate stage can live in the earthworm for an unknown period.

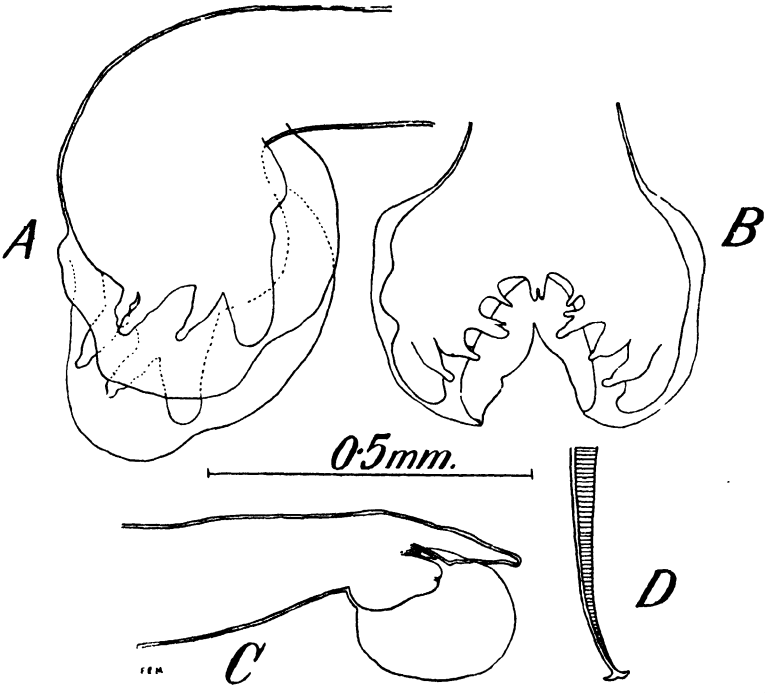

FIG. 139.—*Metastrongylus pudendotectus.* (FROM BAYLIS, AFTER GEDOELST.)
A, Lateral view of bursa; *B*, dorsal view of bursa; *C*, posterior end of female; *D*, tip of spicule. The scale refers to the figures above it.

Genus **Protostrongylus** Kamensky, 1905

P. rufescens (Leuckart, 1865) occurs in the small bronchioles of sheep, goats, deer and possibly also hares and rabbits in Europe, Africa, Australia

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* *Journ. Exp. Med.*, 77 (2): 111-138. 1943.

and North America. Male 16-28 mm., female 25-35 mm. long. The worms are slender and reddish in colour. The bursa is short and strengthened dorso-laterally by a chitinous plate on either side. The ventral, lateral and externo-dorsal rays are present, but the dorsal is replaced by a spherical body which bears six papillæ on its ventral surface. The spicules are about 0·26 mm. long, tubular, with broad, membranous expansions. A gubernaculum is present as well as a strongly developed telamon. The latter is pigmented brown in its posterior portion, where it forms two arms, each provided distally with a number of teeth. The vulva opens near the anus. The eggs are unsegmented when laid and measure 75-120 by 45-82 μ.

Life-Cycle.—The eggs develop in the lungs of the host and the first-stage larva which is passed in the fæces is 0·25-0·32 mm. long. The tip of its tail has a wavy outline, but is devoid of a dorsal spine (*cf. Muellerius*). For its further development the larva requires an intermediate host, which is a flat, spiral-shelled snail of the genus *Helicella*, by which it is swallowed or into which it penetrates through the foot. The development to the infective stage requires 12-14 days and two ecdyses are performed. The final host becomes infected by swallowing the snail with its food and the larvæ pass to the lungs of the host via the mesenteric lymphatic glands, in which the third ecdysis takes place.

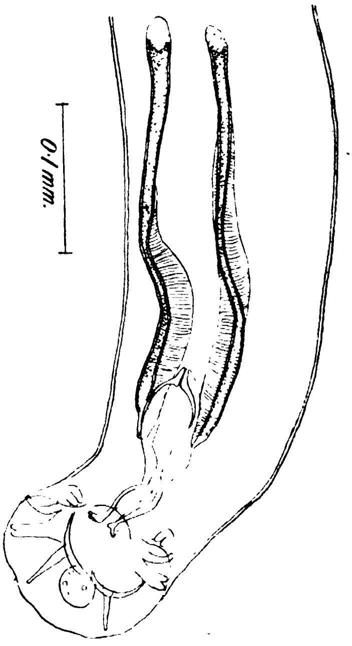

FIG. 140.—*Protostrongylus ocreatus*, POSTERIOR END OF MALE, VENTRAL VIEW. (AFTER BAYLIS.)

Pathogenesis, Pathology and Symptoms.—The worms live in the small bronchioles, where they produce an irritation and local areas of inflammation develop. The resulting exudate fills the alveoli, which are situated distally to the seat of the parasites, and the inflammatory process spreads to the peribronchial tissues. The affected alveolar and bronchial epithelium is desquamated, blood-vessels are occluded and an infiltration with round cells and proliferation of connective tissue take place in the area. The result is a small focus of lobular pneumonia, roughly conical in shape and yellowish-grey in colour. The pleura at the base of the focus may be involved in a fibrinous pleuritis. The number of such foci in the lungs depends on the number of parasites present. As a rule the animals show no definite symptoms, although severe infections would undoubtedly affect the general health, and the weakened lungs are susceptible to bacterial invasion which may produce acute pneumonia.

Diagnosis can be made by finding the larvæ in the fæces.

Treatment unknown.

Prophylaxis.—As in the case of *Dictyocaulus* infection. Where the extermination of the snail intermediate host is possible this should be carried out. Special attention must be paid to the lambs; they should not be run on pastures previously used for infected animals. Pastures may remain infected for a considerable period, as the worm larvæ are protected in the snails. The snails creep up plants in the early morning and evening and in rainy weather and the animals should therefore not be allowed to graze at such times, particularly in the autumn, when the infection most frequently occurs.

Several other species of *Protostrongylus* as well as the closely related *Neostrongylus linearis* occur in sheep and goats, chiefly in Europe, and produce similar lesions in the lungs.

Genus **Muellerius** Cameron, 1927

M. capillaris (Müller, 1889) occurs in the lungs of sheep, goats and chamois in Europe, Australia, South Africa, and the United States. It is probably the commonest lungworm of sheep in Europe. Male 12-14 mm., female 19-23 mm. long. The posterior end of the male is spirally coiled and there is no bursa, but a number of papillæ surround the cloacal opening. The spicules are 0·15 mm. long; they are curved and each consists of a proximal half which is alate and two distal serrated arms ending in sharp points. The vulva opens close to the anus and has a small cuticular swelling on its posterior border. The eggs measure about 100 by 20 μ and are unsegmented when laid.

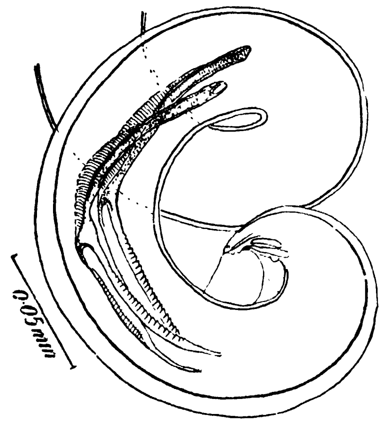

FIG. 141.—*Muellerius capillaris*, POSTERIOR END OF MALE, LATERAL VIEW. (AFTER BAYLIS.)

Life-Cycle.—The eggs develop in the lungs of the host and the first-stage larvæ are passed in the fæces. They are 0·25-0·3 mm. long. The œsophagus has two swellings, one near the middle and the other at the distal extremity. The tail of the larva has an undulating tip and a dorsal snipe (*cf. Protostrongylus*). These larvæ can resist a fair amount of drying, are most active at relatively low temperatures (17°-27°C. according to Morgan) and are not killed by freezing.

For further development they require a snail intermediate host, into which they penetrate through the foot or by which they are swallowed. A large number of species are known to be suitable intermediate hosts; for instance. species of the nude slugs *Limax*, *Agriolimax* and *Arion*, and the snails *Helix* and *Succinea*. The development in the snail and in the sheep is very similar to that of *Protostrongylus*. The infective larvæ can live up to a week after the death of the snail.

Pathogenesis, Lesions and Symptoms.—This parasite is usually not found in lambs under 6 months of age. The adult worms live in the alveoli and the pulmonary parenchyma, especially in the subpleural tissue. Possibly they also live, for a time at least, in the small pulmonary arteries, since their eggs are spread throughout the lungs. The worms produce greyish nodules up to 2 cm. in diameter. These consist of necrotic masses, resulting from the degeneration of accumulated leucocytes and pulmonary tissues, and they are surrounded by a wall of connective tissue and a few giant cells. These nodules may calcify. Smaller separate foci are formed by the eggs which are surrounded by leucocytes and epithelioid cells, while the adjoining pulmonary tissue is hyperæmic and the alveoli become filled with round cells. After the egg has hatched the reaction subsides and the lesion may heal. An adenoma-like proliferation of the bronchial epithelium is seen in some cases.

The infected animal as a rule shows no symptoms, but heavy infections weaken the lungs and assist in reducing the general health and resistance of the host.

Diagnosis can be made by finding the larvæ in the fresh fæces.

Treatment.—Only nursing and good feeding can be recommended.

Prophylaxis.—As in the case of *Protostrongylus*. The nude slugs can be more easily controlled than shelled snails, and spreading of lime has been recommended for this purpose.

Genus **Ælurostrongylus** Cameron, 1927

A. abstrusus (Railliet, 1898) occurs in the lungs of the cat in Europe and the United States. Male up to 7·5 mm., female 9·86 mm. long. The male bursa is short and the lobes are not distinct. All the bursal rays can be distinguished; the dorsal forms two stout branches. The spicules are simple and 0·13-0·15 mm. long. The vulva opens near the posterior extremity and the eggs measure about 80 by 70 μ.

Life-Cycle.—The adult worms live in the smaller branches of the pulmonary artery where they lay their eggs. These become arrested in the capillaries and develop there. The larvæ on hatching break out into the air passages, which they ascend,· and they are passed out in the fæces of the host. They are about 0·36 mm. long and the tail has an undulating appendage of variable shape and usually a dorsal projection. The larvæ live only about a fortnight in the free state. For further development they require snails and slugs*—mainly *Epiphragmophora* spp. and also *Agriolimax agrestis*, *A. columbianus*, *Helix aspersa*, *Helminthoglypta californiensis*, *H. nickliniana*, *H. arrosa*—as intermediate hosts in which two ecdyses occur. Various auxiliary or " transport hosts," such as rodents, frogs, lizards and birds, which eat infected snails and in which the worm larvæ encyst, may aid in infecting cats. The larvæ penetrate the mucosa of the œsophagus, stomach or intestine of the cat and, via the blood, reach the lungs, where they grow adult in about 6 weeks.

Pathogenesis, Lesions and Symptoms.—As far as is known the adult parasites are not pathogenic. The eggs, after having been arrested in the capillaries, become surrounded by small thrombi. A small infarct in the adjacent pulmonary tissue with atelectasis and catarrh of the affected alveoli follows. There is no accumulation of eosinophiles. After hatching of the egg the thrombus becomes organised and the lesion may disappear completely.

In heavy infections the animal may cough and suffer from diarrhœa and emaciation, which may be followed by death, or recovery may take place. In very severe infections the simultaneous deposition of a large number of eggs in the lungs may cause sudden death.

Diagnosis can be made by finding the larvæ in the fæces.

Treatment.—Only symptomatic treatment can be recommended.

Prophylaxis is in most cases impracticable, since it would imply preventing cats from catching mice, lizards, etc.

Genus **Angiostrongylus** Kamensky, 1905

A. vasorum (Baillet, 1866) (syn. *Hæmostrongylus vasorum*) occurs in the pulmonary artery and rarely in the right ventricle of the dog and fox. Male 14-18 mm., female 18-25 mm. long and relatively stout. The bursa is small, but all the rays can be distinguished; the ventrals are fused for most of their length and the dorsal ray is stout with short terminal branches. The vulva is situated in the posterior half of the body. The eggs measure 70-80 by 40-50 μ and are unsegmented when laid.

Life-Cycle.—The eggs are arrested in the lung capillaries, where they develop and hatch. The larvæ escape into the air passages and are passed in the fæces of the host. They have a pointed tail with a small appendage. The rest of the life-cycle is unknown.

Pathogenesis, Lesions and Symptoms.—The parasites and their eggs cause obliteration of the small pulmonary arterial branches through irritation of the vascular walls. This later leads to perivascular sclerosis and pulmonary emphysema. Nodules of various sizes, consisting of partly organised thrombi, may be present in the lungs. Hypertrophy of the heart and congestion of the liver with consequent ascites follow on the lung disturbances. Affected animals suffer from dyspnœa and may die of cardiac insufficiency.

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* Hobmaier, *Proc. Soc. Exp. Biol. Med.*, 32: 1641-1647. 1935.

Diagnosis.—The worms are usually found at autopsy, but in cases of dyspnœa a diagnosis might be made by finding the larvæ in the sputum or fresh fæces. Since no detailed description of the larvæ is available the diagnosis could be tentative only. The larvæ must be distinguished from those of *Strongyloides stercoralis* and *Oslerus osleri.*

Treatment.—No treatment is known. Carbon tetrachloride may be useful.

Prophylaxis.—Since the life-cycle is unknown, nothing beyond hygienic measures can be recommended.

Genus **Filaroides** v. Beneden, 1858 (syn. *Oslerus*)

F. osleri (Cobbold, 1879) occurs in nodules in the trachea and bronchi and rarely in the lungs of the dog. The worm is not frequently seen, although it has been found in America, England, India, South Africa and New Zealand. Male 5 mm. long and slender, female 9-15 mm. long and stouter. The hind end of the male is rounded and bears a few papillæ. The spicules are short and slightly unequal. The vulva is close to the anus and the worms lay eggs with thin shells, containing larvæ and measuring about 80 by 50 μ. The larva has a short S-shaped tail.

Life-cycle unknown.

Pathogenesis, Lesions and Symptoms.—The worms live in or under the mucosa of the trachea or bronchi and cause the development of small tumours. These are greyish-white or pink in colour, usually less than 1 cm. in diameter, polypoid or sessile and of the nature of a granuloma, with cavities in which the worms are lodged. According to Hare (1930), the cystic spaces appear to be enlarged acini of bronchial mucous glands. The symptoms depend on the severity of the infection and the size and number of the tumours. Chiefly young dogs are affected and the disease is chronic and usually not fatal. The most marked symptom is a rasping, persistent cough. Loss of appetite and emaciation may be noted.

Diagnosis can be made by bronchoscopy or by finding the eggs in the sputum.

Treatment.—Only symptomatic treatment can be recommended. Ascoli (1936) found that intratracheal injections of 1 c.c. 5 per cent. phenol cause the symptoms to disappear. According to an experience of Pillers* it would seem that during 4-5 months' rest in a clean, insect-free loose-box the worms may die off and the nodules disappear.

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* *Vet. Rec.*, 15 (3): 62-63. 1935.

Prophylaxis.—General hygienic measures are indicated, while the life-cycle is unknown.

Genus Crenosoma

C. vulpis (Dujardin, 1845) occurs in the bronchi and sometimes also the trachea of the fox. Male 3·5-8 mm., female 12-15 mm. long. Anteriorly the cuticula is armed with 18-26 prominent circular ridges which bear small spines. The ventral rays are partly fused and also the medio- and postero-laterals; the externo-dorsals arise separately; the dorsal is stout and bears two small processes distally. The spicules are about 0·37 mm. long and each has a slender dorsal spur in the posterior third. A gubernaculum is present. The vulva is situated near the middle of the body. The worms are viviparous and produce larvæ which are 0·265-0·33 mm. long. The œsophagus of the larva is 0·105-0·113 mm. long and the tail 0·035-0·036 mm. There is a fairly transparent vestibulum, and the intestine consists of 14-16 cells.

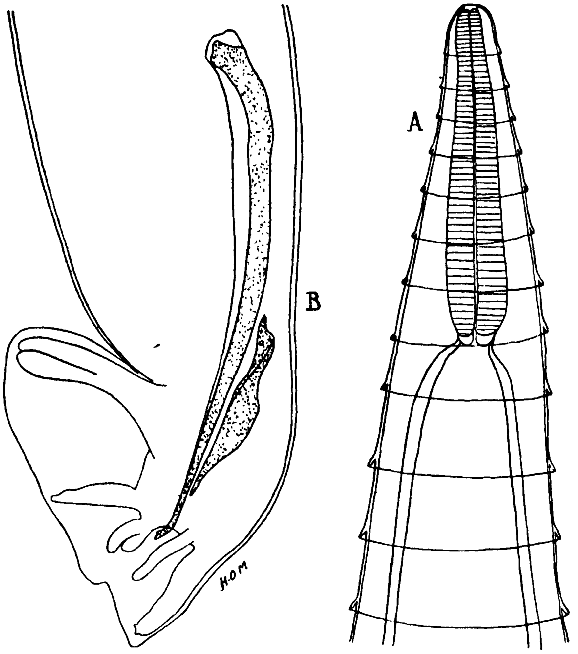

FIG. 142.—*Crenosoma vulpis.* (ORIGINAL.)
A, Anterior end, dorsal view; B, hind end of male, lateral view.

Life-Cycle.—Wetzel (1935) found that the larvæ penetrate into the foot of land snails or slugs (*Helix pomatia, Cepea hortensis, C. nemoralis, Arianta arbustorum, Agriolimax agrestis, Arion hortensis, A. circumscriptus*) in which they reach the infective stage in 16-17 days. When such snails are eaten by the final host the larvæ pass via the lymphatic glands to the blood and lungs, where they grow adult in 21 days.

Pathogenicity and Symptoms.—Similar to the description given under *Capillaria aerophila.* American authors regard the latter parasite as the more pathogenic of the two, while Sprehn considers that *C. vulpis* is more frequently the primary cause of bronchitis and pneumonia, and that these are due to secondary infection in the case of *C. aerophila.*

Diagnosis can be made by finding the larvæ in the fresh fæces or nasal discharge.

Treatment by means of the tracheal brush is not effective, since the parasites are lodged mainly in the bronchi. Diseased animals should be kept on wire floors and well fed.

Prophylaxis.—The runs have to be kept dry and free of grass in order to produce conditions which are unsuitable for the intermediate host. To keep out snails Sprehn recommends a board, 20-30 cm. high, surrounding the run and painted on the outside with tar and oil.

Order SPIRUROIDEA

Nematodes with two lateral lips which may be further subdivided. A pharynx or cylindrical buccal capsule is usually present. The œsophagus consists of a short, anterior, muscular portion followed by a longer, wide, glandular portion. The hind end of the male is usually spirally coiled and bears lateral alæ and papillæ. The spicules are as a rule unequal and dissimilar. The vulva opens near the middle of the body in most cases, but its position is variable. The eggs are usually thick-shelled and contain larvæ when laid. The adults are parasites of vertebrates, frequently living in the lumen or the wall of the stomach. The life-cycle as a rule includes an intermediate host which is an arthropod.

Family SPIRURIDÆ

With the typical characteristics of the order.

Genus Habronema Diesing, 1861

H. muscæ Carter, 1861, occurs in the stomach of equines. Male 8-14 mm., female 13-22 mm. long. There are two lateral lips, each being trilobed. The pharynx is cylindrical and provided with a thick cuticular lining. The male has wide caudal alæ, four pairs of precloacal papillæ and one or two papillæ behind the cloaca. The cloacal region of the body is covered with small cuticular bosses or ridges. The left spicule is slender and 2·5 mm. long, the right stouter and only 0·5 mm. long. The vulva is situated near the middle of the body and opens dorso-laterally, the vagina running for some distance in the body wall. The eggs have thin shells and measure 40-50 by 10-12 μ.

H. microstoma (Schneider, 1866), also a parasite in the stomach of equines, closely resembles the preceding species. It is larger, the male being 16-22 mm. long and the female 15-25 mm. The pharynx contains a dorsal and a ventral tooth in its anterior part. The male has four pairs of precloacal papillæ. The left spicule measures 0·76-0·8 mm. and the right 0·35-0·38 mm. The eggs measure 45-49 by 16 μ and hatch in the uterus of the female.

H. megastoma (Rudolphi, 1819) occurs in tumours of the stomach wall, rarely free in the stomach of equines. Male 7-10 mm., female 10-13 mm. long. It can easily be recognised by its "head," which is constricted off from the body. The pharynx is funnel-shaped. The male has four pairs of precloacal papillæ. The left spicule is 0·46 mm. long and the right 0·24 mm. The worms are viviparous.

Life-Cycle.—The larvæ are passed in the fæces of the host and are ingested by the maggots of flies which develop in the manure. *H. muscæ* and *H. megastoma* develop in the house fly, *Musca domestica*, while *H. microstoma* develops in the stable fly, *Stomoxys calcitrans*. The worms reach the infective stage in the maggot at about the time when the latter pupates. In the adult fly the larvæ occur free in the body cavity and may pass forward into the proboscis. In the case of *Stomoxys* the larvæ escape into the wound when the fly sucks blood and they may also escape from the proboscis of *Musca* when this fly feeds on the lips or wounds of horses. In this way infection of the final host may occur, but more usually the animal will become infected by swallowing flies that fall into its food or water. The larvæ are liberated in the stomach, where they grow to maturity.

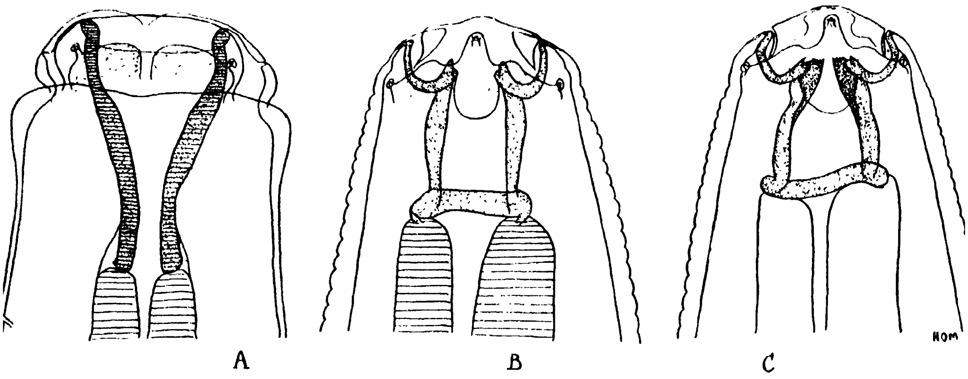

FIG. 143.—*Habronema* SPECIES OF EQUINES, HEADS IN LATERAL VIEW. (ORIGINAL.)

A, *H. megastoma* ; B, *H. muscæ* ; C, *H. microstoma.*

Pathogenesis.—*H. megastoma* produces large tumours of the stomach wall which have one or more openings and a number of cavities in which the worms are located. These tumours may interfere mechanically with the function of the stomach, but are otherwise not particularly harmful.

The other two species occur free in the stomach and may penetrate into the mucosa. They produce an irritation which leads to a chronic catarrhal gastritis with the formation of much mucus. *H. microstoma* may produce ulcers of the stomach.

Cutaneous habronemiasis, also known as " summer sores," " bursati," " granular dermatitis," etc., is caused by *Habronema* larvæ which are deposited in existing wounds by infected flies. The larvæ are not able to penetrate the intact skin. Although some authors contradict this idea, there can be no doubt that the condition is caused in this way. Van Saceghem (1918) and Bull (1919) showed respectively that the typical lesions develop in exposed wounds, while protected wounds remain unaffected and that small granulomata can be produced experimentally with larvæ of *H. megastoma*. The larvæ have been found in the wounds in natural cases. A nodular conjunctivitis of similar origin is also known and has been produced experimentally by Van Saceghem with larvæ of *H. muscæ*.

Symptoms and Lesions.—Gastric habronemiasis is not known to cause marked symptoms, but it is probably the cause of some cases of chronic gastritis. If the tumours of *H. megastoma* occur near the pylorus they may interfere with the closing of the sphincter and cause digestive disorders.

The lesions of cutaneous habronemiasis occur mainly in warm countries and during the summer. They are seen on those parts of the body that are liable to be injured, such as the legs, withers, sometimes the sheath and in the canthus of the eye. They vary in size and have an uneven surface which consists of a soft, brownish-red material and which covers a mass of firmer granulations. The wounds show a tendency to increase in size and do not respond to ordinary treatment until the following winter, when they often heal up spontaneously. In some cases chronic lesions develop in the form of granulomas which may reach a considerable size.

In some horses, especially those that have had cutaneous habronemiasis, the lungs show at autopsy numerous small, hard, yellowish-grey nodules. These have a caseous or brittle centre which is easily enucleated and on microscopic examination is seen to contain a nematode larva. The central mass is surrounded by eosinophiles and a fibrous capsule. These nodules should be distinguished from glanders or tubercular nodules.

Diagnosis.—The gastric infection is difficult to diagnose because the larvæ are not readily found in the fæces. Some worms or larvæ may be found by gastric lavage through a stomach tube. Descazeaux and Morel* recommend incubating the fæces with washed eggs of the house fly and later finding the larvæ in the flies. This is only successful in the warm season.

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* *Bull. Soc. Path. Exot.*, 26 (8): 1010-1014. 1933.

Treatment.—The animal should be starved overnight and in the morning 8-10 litres of a 2 per cent. solution of sodium bicarbonate at body temperature are administered into the stomach by means of a stomach tube, in order to loosen the mucus in which the worms lie. The fluid should be withdrawn if possible, but usually it passes into the intestine. Carbon bisulphide is then administered through the tube at the rate of 5 c.c. per 100 kilos bodyweight (6 drams per 1,000 lbs. or more), followed by a small quantity of water to wash down the drug. This treatment is effective for *H. muscæ* and *H. microstoma*. The worms in the tumours cannot be reached. Carbon tetrachloride also kills a fair proportion of these worms.

For cutaneous habronemiasis the following powder is applied until the wound has healed: plaster of paris 100, alum 20, naphthalin 10 and quinine 10. The latter ingredient is to prevent the animals from biting the wound and may be replaced by a sufficient amount of any bitter powder. French authors claim good results from freezing summer sores three to four times daily by means of ethyl chloride or liquid carbon dioxide. Habronemic granulomas should be removed as early as possible, especially during the winter, when they tend to become smaller.

Prophylaxis.—Habronemiasis can be controlled effectively by hygienic manure disposal (p. 319), which controls flies and kills the worm larvæ by the heat of the fermenting manure. Further measures should be taken against flies in stables and against the contamination of food and water by flies. The cutaneous infection can be prevented by suitable protection of all wounds.

Genus **Hartertia** Seurat, 1915

H. gallinarum (Theiler, 1919) occurs in the small intestine of the fowl and wild bustards in Africa. Male 28-40 mm., female 60-110 mm. long. Macroscopically the worms closely resemble *Ascaridia galli*. They have two lateral lips, each divided medially into three lobes. The male hind end has lateral alæ, ventral cuticular bosses, four pairs of precloacal and two pairs of postcloacal papillæ. The anterior lip of the cloaca bears a cuticular thickening, which may resemble a papilla. The left spicule is 2·3 mm. long, acutely pointed and provided with four large barbs, while the right is 0·63 mm. long and ends bluntly. The vulva opens in the anterior third of the body. The eggs have thick shells; they measure 45-53 by 27-33 μ and contain fully developed embryos when laid.

Life-Cycle.—The eggs are passed in the fæces of the host and for further development have to be ingested by certain termites (*Macrohodothermes mossambicus transvaalensis*). Only the workers become infected. The larvæ develop in the body cavity of the termite and reach a length of 1 cm. or more. The termites do not appear to suffer from the parasites. Fowls become infected by ingesting such termites and the worms grow to maturity in the bird in 3 weeks, according to Theiler.

Pathogenicity.—Depending on the severity of the infection, the parasites produce various degrees of emaciation, weakness, diarrhœa, decrease of egg production or death.

Diagnosis can be made by finding the eggs in the fæces, but it may not always be possible to distinguish them from eggs of other spirurids occurring in fowls. Diagnosis should therefore be confirmed by autopsy of a selected case.

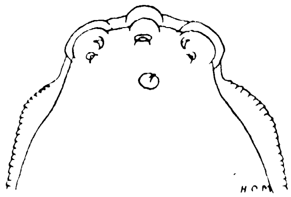

FIG. 144.—*Hartertia gallinarum*, ANTERIOR END, LATERAL VIEW. (ORIGINAL.)

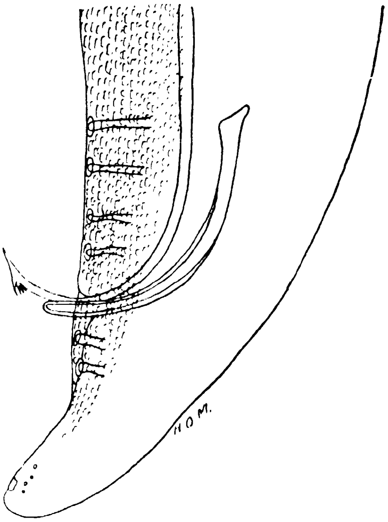

FIG. 145.—*Hartertia gallinarum*, HIND END OF MALE, LATERAL VIEW. (ORIGINAL.)

Treatment.—As in the case of *Ascaridia galli.*

Prophylaxis.—All termites in the vicinity of the fowl runs have to be destroyed.

Genus Spirocerca Railliet and Henry, 1911

S. lupi (Rudolphi, 1809) (syn. *S. sanguinolenta*) occurs in the walls of the œsophagus, stomach and aorta, and more rarely free in the stomach and in other organs of the dog, fox, wolf and jackal. It is common in most warm countries. The worms are usually coiled in a spiral and have a blood-red colour. Male 30-54 mm., female 54-80 mm. long and rather stout. The lips are trilobed and the pharynx is short. The male tail bears lateral alæ, four pairs and one unpaired median precloacal papilla and two pairs of postcloacals, while a group of minute papillæ is situated near to the tip of the tail. The left spicule is 2·45-2·8 mm. long, the right 0·475-0·75 mm. The eggs have thick shells; they measure 30-37 by 11-15 μ and contain larvæ when laid.

Life-Cycle.—The eggs are passed in the fæces of the host and hatch only after they have been ingested by a suitable coprophagous beetle (*Scarabeus sacer* and others). The larvæ develop to the infective stage and become encysted in the beetle, chiefly on the tracheal tubes. If such beetles are swallowed by an unsuitable host, the larval worms become encysted again in the œsophagus, mesentery or other organ of this host. Such cysts have been found in numerous amphibia, reptiles, birds and small mammals. The final host may become infected by ingesting either beetles that contain infective larvæ or other animals in which the encysted forms occur. On being liberated in the stomach the larvæ penetrate into the stomach wall* and, reaching the arteries, migrate in the walls of the coronary and gastro-epiploic arteries to the cœliac artery and thence to the aorta, reaching the upper thoracic aorta in about 3 weeks. Some may enter veins and reach other organs. The walls of the œsophagus and stomach are apparently also reached via the blood.

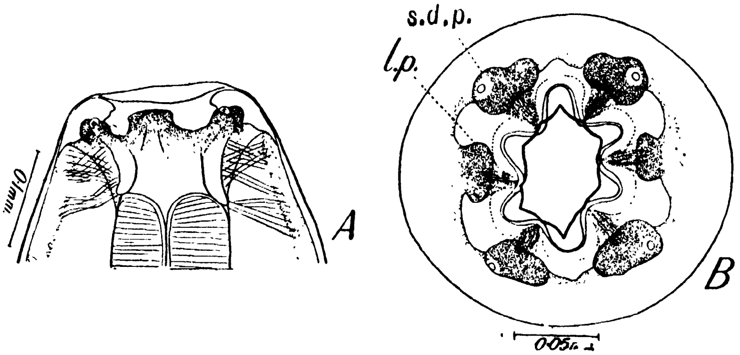

Fig. 146.—*Spirocerca lupi*, Anterior End of Female. (After Baylis.)
A, Lateral view; *B*, *en face* view; *l.p.*, lateral papilla; *s.d.p.*, subdorsal papilla.

Pathogenesis.—The migrating larvæ produce hæmorrhages, inflammatory reactions and necrosis, as well as purulent streaks or abscesses in the tissues in which they penetrate. These lesions heal rapidly after the larvæ have passed on, but stenosis of the vessels may remain. The adult parasites produce tumours in the œsophagus, stomach and aorta, which contain cavities that harbour one or more of the worms. The tumours in the wall of the aorta may lead to stenosis, formation of aneurysm or rupture of the vessel, followed by fatal hæmorrhage. Tumours in the œsophagus or stomach may produce stenosis and marked irritation. In the bronchi, lymphatic glands and the peritoneal and pleural cavities the parasites may cause various disturbances.

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* Hu and Hoeppli, *Chin. Med. Journ.*, Suppl. 1: 293-311. 1936. *Proc. Soc. Exp. Biol. Med.*, 32 (9): 1393-1394. 1935.

Symptoms.—The œsophageal tumours may cause interference with deglutition, respiration and circulation. Those in the stomach produce vomiting which is at times so persistent that the animal is unable to retain its food and loses condition rapidly. Sometimes worms may be passed in the vomit. In less serious cases the tumours cause difficulty in swallowing or interfere mechanically with the action of the stomach. Aortic infection is usually not observed until sudden death is caused by rupture.

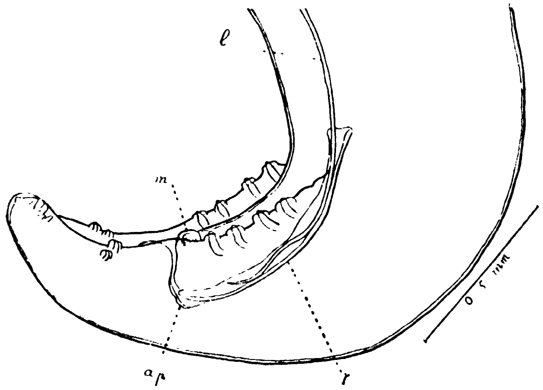

FIG. 147.—*Spirocerca lupi*, POSTERIOR END OF MALE, LATERAL VIEW. (AFTER BAYLIS.) *a.p.*, Accessory piece; *l.*, left spicule; *m.*, median preanal papilla; *r.*, right spicule.

Diagnosis.—Infections in the alimentary canal can be diagnosed by finding the eggs in the fæces or the vomit, but eggs are not passed unless the tumour has acquired an opening into the lumen of the organ. It may be difficult to differentiate this infection from one with *Physaloptera* in the stomach. Aortic infection will only be diagnosed tentatively on account of the presence of stenosis or aneurysm.

Treatment.—Only palliative measures can be applied, since no remedy is known against the worms. Carbon tetrachloride, which may act on the worms through the blood, may be useful.

Prophylaxis.—Infected animals should be isolated and their vomit and fæces disposed of so that the infection is not allowed to spread. Healthy animals should be prevented as far as possible from eating dung beetles, frogs, mice, hedgehogs, lizards, etc., which may carry the encysted larvæ.

S. arctica Petrow, 1927, occurs in the dog, fox and wolf (*Vulpes lagopus*) in Northern Russia.

Family ASCAROPIDÆ (*syn.* ARDUENNIDÆ)

The lips are small and the wall of the pharynx is often provided with spiral or annular thickenings. The male tail is spirally coiled and its alæ and papillæ are usually asymmetrical.

Genus **Ascarops** v. Beneden, 1873 (*syn.* Arduenna)

A. strongylina (Rudolphi, 1819) occurs in the stomach of the pig and wild boar in most parts of the world. Male 10-15 mm., female 16-22 mm. long. A cervical ala is present only on the left side of the body. The pharynx is 0·083-0·098 mm. long and its wall is strengthened by thickenings in the form of a triple or quadruple spiral. The right caudal ala of the male is about twice as large as the left and there are four pairs of precloacal papillæ and one pair of postcloacals, all situated asymmetrically. The left spicule is 2·24-2·95 mm. long and the right 0·46-0·62 mm. The eggs measure about 40 by 22 μ and have thick shells surrounded by a thin membrane which produces an irregular outline. They contain larvæ when laid.

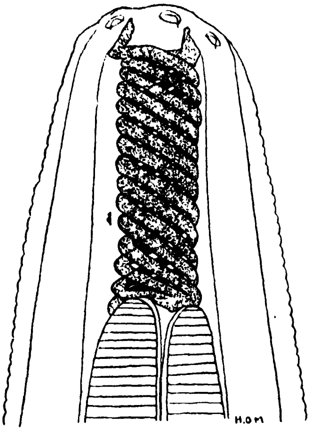

FIG. 148.—*Ascarops strongylina*, ANTERIOR END, LATERAL VIEW. (ORIGINAL.)

Life-Cycle.—The eggs are passed in the fæces of the host, and when they are swallowed by coprophagous beetles (species of *Aphodius*, *Onthophagus* and *Gymnopleurus*), the larvæ develop in these to the infective stage. Pigs become infected by ingesting such beetles.

A. dentata (von Linstow, 1904) is a larger species than the preceding one and occurs in pigs in Indo-China and the Malay region. The buccal capsule is provided with a pair of teeth anteriorly.

Genus **Physocephalus** Diesing, 1861

P. sexalatus (Molin, 1860) occurs in the stomach of the pig and has also been recorded from some other animals; for instance, hares and rabbits. Male up to 8 mm., female up to 17 mm. long. The cuticle of the anterior extremity is slightly inflated in the region of the pharynx. This inflation is followed by three cervical alæ on either side. The cervical papillæ are very asymmetrically situated. The pharynx is

0·263-0·315 mm. long and its walls are strengthened by a single spiral thickening which breaks up into complete rings in the middle portion. The caudal alæ of the male are narrow and symmetrical, and there are four pairs of precloacal papillæ and the same number of postcloacals. The left spicule measures 2·1-2·25 mm. and the right 0·3-0·4 mm. The eggs have thick shells, contain larvæ when laid and measure 34-39 by 15-17 μ.

Life-Cycle.—Similar to that of *Ascarops*. A large number of beetles are known to act as intermediate hosts, including species of *Scarabeus*, *Phanæus*, *Gymnopleurus*, *Geotrupes* and *Onthophagus*. As in the case of *Spirocerca* the larvæ become encysted, chiefly in the walls of the alimentary canal, in unsuitable hosts which swallow infected beetles. Cram (1930) found that birds which had eaten beetles on a field used for pigs harboured numerous cysts with these larvæ, but their health was not affected. In the pig the larvæ penetrate deeply into the mucosa of the stomach and grow adult in about 6 weeks.

Pathogenesis.—*Ascarops* and *Physocephalus* are common stomach worms of pigs, but cause no marked disturbance unless they occur in fairly large numbers or the resistance of the animal is weakened by another factor, when the worms irritate the mucosa and produce an inflammation.

Symptoms.—Affected animals, especially young ones, show symptoms of a chronic or acute gastritis. They lose their appetite, but usually have a marked thirst. Growth is retarded or emaciation and even death may occur.

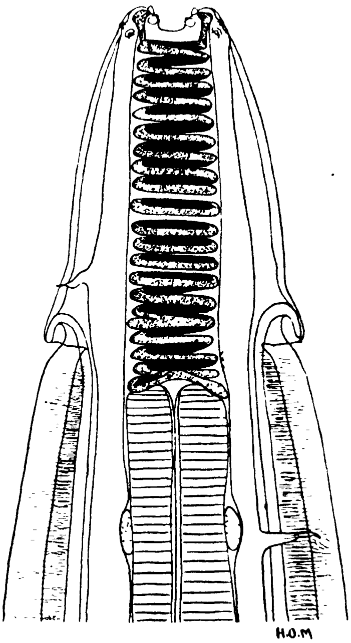

Fig. 149.—*Physocephalus sexalatus*, Anterior End, Dorsal View. (Original.)

Post-Mortem.—The gastric contents are small in quantity and there is much mucus. The mucosa, particularly in the fundus region, is reddened and swollen, or it may be covered with pseudo-membranes, underneath which the tissues are markedly reddened and ulcerated. The worms are found free or partly embedded in the mucosa.

Diagnosis can be made by finding the eggs of the worms in the fæces.

Treatment.—Carbon bisulphide is recommended as for *Hyostrongylus rubidus* (p. 207).

Prophylaxis.—Infected pigs should not be allowed to disseminate the eggs with their fæces and the latter should therefore be disposed of in a suitable way. Healthy pigs should be prevented as far as possible from ingesting dung beetles. The measures advocated for the prevention of *Ascaris* will be effective against the spirurids of pigs to a certain extent, but dung beetles may fly a fair distance.

Simondsia paradoxa Cobbold, 1864, occurs in the stomach of pigs in Europe. The worm is peculiar in that the females are lodged in small cysts in the stomach wall with the posterior parts of their bodies, which are globular in shape, while the anterior, slender portion protrudes. The male has a cylindrical body, 12-15 mm. long, and occurs free or partly embedded in the mucosa.

Genus **Gongylonema** Molin, 1857

G. pulchrum Molin, 1857 (syn. *G. scutatum*) occurs in the sheep, goat, cattle, pig, zebu, buffalo and less frequently the horse, camel, donkey and wild boar. It is found in most parts of the world. The form described from man as *G. hominis* Stiles, 1921, is regarded by Baylis as identical with *G. pulchrum.* The worm inhabits the œsophagus, where it

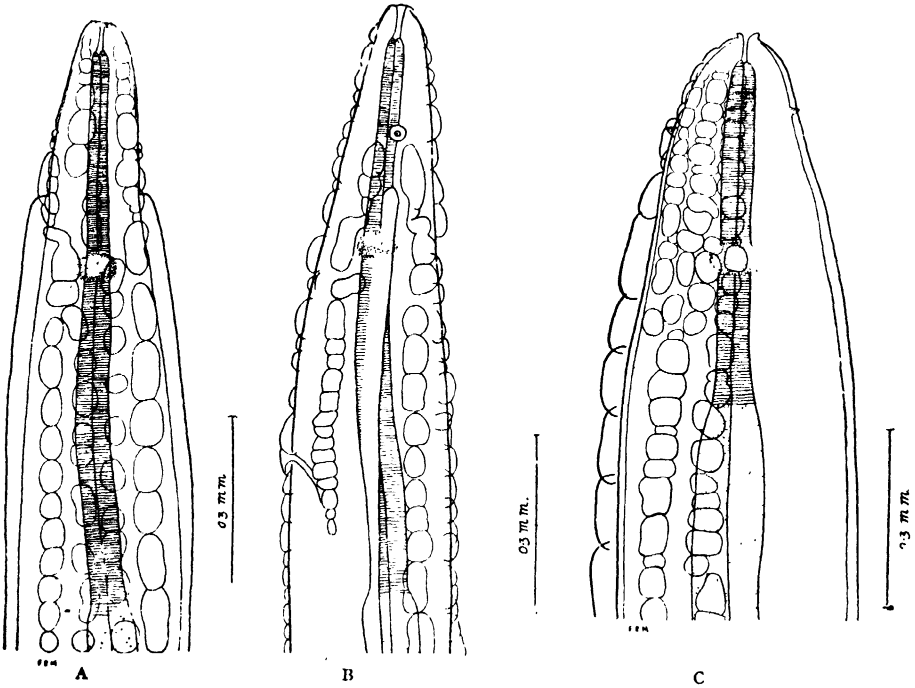

FIG. 150.—A, *Gongylonema pulchrum*, ANTERIOR END, DORSAL VIEW; B, THE SAME, LATERAL VIEW; C, *Gongylonema verrucosum*, ANTERIOR END, DORSAL VIEW. (AFTER BAYLIS.)

lies in zigzag fashion embedded in the mucosa or submucosa. In ruminants it may also occur in the rumen. Male up to 62 mm., female up to 145 mm. long. The cuticle of the anterior end bears a number of round or oval thickenings of various sizes. The cervical alæ are well developed. The lips are small and there is a short pharynx with simple walls. The tail of the male is alate, somewhat asymmetrical, and bears a number of papillæ which are also asymmetrically arranged. The left spicule is slender and 4-23 mm. long. The right is 0·084-0·18 mm. long and stout. A gubernaculum is present. The vulva opens posteriorly and the eggs measure 50-70 by 25-37 μ.

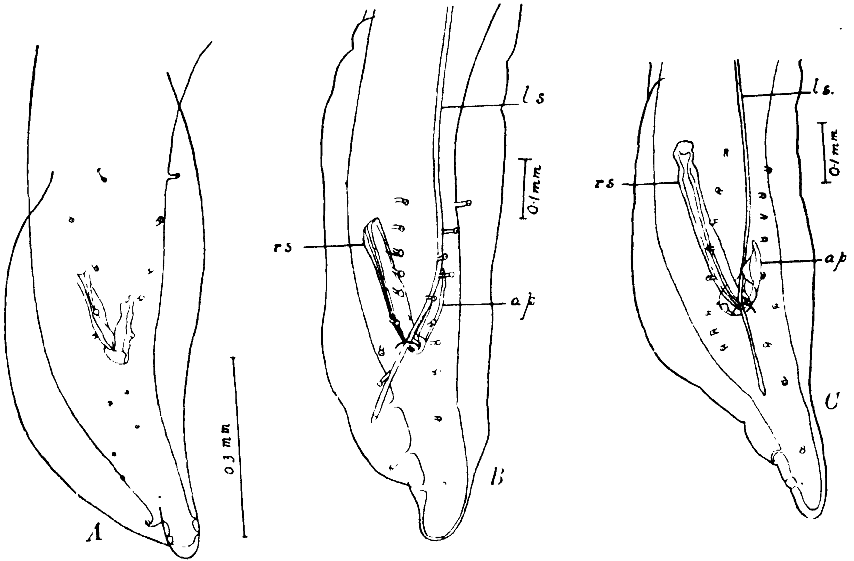

FIG. 151.—POSTERIOR END OF MALE, VENTRAL VIEW, OF A, *Gongylonema pulchrum*; B, *G. mönnigi*; C, *G. verrucosum*. (AFTER BAYLIS.)
a.p., Accessory piece; *l.s.*, left spicule; *r.s.*, right spicule.

The forms found in the pig are consistently smaller than those found in ruminants and they were formerly considered to be a distinct species. Baylis and others have, however, transmitted the worms from ruminants to pigs and vice versa.

Life-Cycle.—The eggs of the parasite are passed in the fæces of the host and hatch after they have been swallowed by coprophagous beetles of the genera *Aphodius*, *Onthophagus* and others, in which the larvæ develop to the infective stage. The small cockroach *Blatella germanica* can be infected experimentally. Infection of the final host takes place by ingestion of the infected beetles. Baylis has shown that the larvæ will emerge spontaneously from cockroaches which fall into water, but it is improbable that such larvæ would be important as a source of infection. By what route the larvæ reach the wall of the œsophagus is not known. They probably escape from the intermediate host in the stomach and may crawl back into the œsophagus or, more probably, reach their destination via the bloodstream.

G. verrucosum (Giles, 1892) occurs in the rumen of sheep, goat, cattle, deer and zebu in India, the United States and South Africa. The worms have a reddish colour when fresh. Male 32-41 mm., female 70-95 mm. long. This species has a festooned cervical ala as well as cuticular bosses on the left side only. The left spicule is 9·5-10·5 mm. long and the right 0·26-0·32 mm.

G. mönnigi Baylis, 1926, occurs in the rumen of the sheep and goat in South Africa. Male 42 mm., female 102-113 mm. long. It resembles *G. verrucosum*, but the cervical ala is not festooned. The left spicule is about 15 mm. long and the right 0·26 mm. The gubernaculum also differs from that of the preceding species.

G. ingluvicola Ransom, 1904, and *G. crami* occur in the crop of the fowl. The eggs measure about 58 by 35 μ. Cram infected *Blatella germanica* with this worm.

Pathogenicity.—The Gongylonemas have no pathogenic importance. It has been found that a related species in rats (*G. neoplasticum*) stimulates the development of malignant growths. The forms occurring in the rumen of sheep are sometimes mistaken by laymen for *Hæmonchus*.

Family ACUARIIDÆ

The cuticle of the anterior part of the body is ornamented with "cordons"—cuticular ridges or grooves—or epaulette-like thickenings. The lips are usually small and triangular in shape and the pharynx is cylindrical. Parasites in the walls of the gizzard, proventriculus, œsophagus or crop of birds.

Genus **Acuaria** Bremser, 1811

The species of this genus are characterised by the presence of four cordons on the anterior end of the body. They are grouped in a number of subgenera which are considered as separate genera by some authors.

A. (Cheilospirura) hamulosa (Diesing, 1851) occurs in the gizzard of the fowl and turkey in most countries. Male 10-14 mm., female 16-29 mm. long. The cordons are double cuticular ridges with an irregular outline and extend far back along the body. The male has four pairs of precloacal and six pairs of postcloacal papillæ. The left spicule is slender and 1·63-1·8 mm. long, the right flattened and 0·23-0·25 mm. long. The vulva is situated just behind the middle and the eggs measure 40-45 by 24-27 μ.

Life-Cycle.—The eggs pass out in the fæces of the host and hatch after they have been swallowed by the intermediate hosts, which are grasshoppers, various beetles and weevils. In these hosts the infective larva develops and the final host acquires the infection by ingesting such insects.

Pathogenesis.—The parasites live underneath the horny lining of the gizzard, producing soft nodules in the musculature and thus weakening it. They also appear to have a toxic effect on the host.

Symptoms.—Mild infections are usually not noticed, also not at autopsy, on account of the location of the worms. Severe infections produce emaciation, droopiness, weakness and anæmia. Cases have been described in which the gizzard was weakened to such a degree that a rupture in the form of a large sac developed.

Post-Mortem.—In mild infections the worms are noticed only if the horny lining of the gizzard is removed. They are found in soft, yellowish-red nodules which are most frequently seen in the thinner parts of the wall. In severe cases the horny lining may be partly destroyed, and the worms are found below the necrotic material in the altered musculature.

Diagnosis.—Several species of *Acuaria* may occur in fowls and turkeys and their eggs are difficult to distinguish from one another. Spirurid eggs in the fæces would lead to a tentative diagnosis, which has to be confirmed at autopsy of a selected case.

Treatment.—No remedy is known.

Prophylaxis is difficult in the case of birds that run free, since they cannot be prevented from eating the intermediate hosts. Where the infection is troublesome the birds have to be kept confined on bare ground and the entrance of insects into the runs, as well as meal beetles and weevils into the food, must be prevented.

A. (Dispharynx) spiralis (Molin, 1858) occurs in the walls of the proventriculus and œsophagus, more rarely in the intestine, of the fowl, turkey, pigeon, guinea-fowl, pheasant and other birds in many countries. Male 7-8·3 mm., female 9-10·2 mm. long. The cordons have a sinuous course and are recurrent, but do not anastomose. The male has four pairs of precloacal and five pairs of postcloacal papillæ. The left spicule is slender and 0·4-0·52 mm. long, the right 0·15-0·2 mm. long and boat-shaped. The vulva is situated in the posterior part of the body. The eggs measure 33-40 by 18-25 μ; they have thick shells and contain larvæ when laid.

Life-Cycle.—The eggs hatch after having been swallowed by the intermediate host, which is an isopod (*Porcellio lævis*, *P. scaber* and *Armadillidum vulgare*) according to Piana and others. The larvæ develop in the body cavity of the isopod, and when the latter is eaten by a suitable bird the parasite grows to maturity in it.

Pathogenesis, Lesions and Symptoms.—The effects of the parasites vary with the severity of the infection. If few are present they do apparently not penetrate into the mucosa, which may then show inflammation and thickening only; but in severe infections deep ulcers, in which the anterior extremities of the worms are embedded, may be seen in the proventriculus. There is an extensive destruction of the glands of this organ and a marked cellular infiltration of the underlying tissues. The affected birds, particularly young ones, rapidly lose weight in spite of a voracious appetite and become very weak and anæmic. In pigeons the iris grows pale as a result of the anæmia. This parasite may cause severe losses.

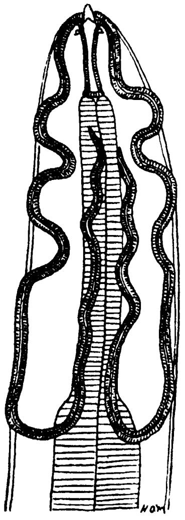

FIG. 152.—*Acuaria* (*Dispharynx*) *spiralis*, ANTERIOR END, LATERAL VIEW. (ORIGINAL.)

Diagnosis.—As in the case of *A. hamulosa.*

Treatment. — No satisfactory remedy is known. Tetrachlorethylene or carbon tetrachloride may be useful.

Prophylaxis. — Where this parasite is troublesome the birds should be confined on bare ground and measures taken to combat the intermediate hosts.

A. (Echinuria) uncinata (Rudolphi, 1819) occurs in the œsophagus, proventriculus, gizzard and small intestine of the duck, goose, swan and wild aquatic birds. Male 8-10 mm., female 12-18·5 mm. long. The cordons run backwards and anastomose in pairs. The cuticle bears also four longitudinal rows of spines. The left spicule is 0·706 mm. long and the right 0·208 mm. There are four pairs of precloacal and four pairs of postcloacal papillæ; the precloacals stand in two groups of two on either side. The vulva is situated near the posterior extremity and the eggs measure 37 by 20 μ.

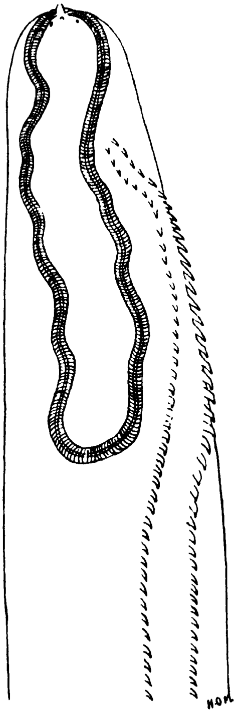

FIG. 153.—*Acuaria* (*Echinuria*) *uncinata*, ANTERIOR END, LATERAL VIEW. (ORIGINAL.)

Life-Cycle.—The eggs are passed in the fæces of the bird and, according to Hamann, are swallowed by water fleas (*Daphnia pulex*), in which they hatch and the infective larvæ develop.

When suitable aquatic birds ingest the infected intermediate hosts the parasites develop to maturity.

Pathogenesis, Lesions and Symptoms.—The worms penetrate into the wall of the alimentary canal, causing a marked inflammation and the formation of nodules which have a caseous content. In the proventriculus and the gizzard the nodules may become so large that they cause mechanical interference and even obstruction to the passage of food. The birds become dull, the feathers are ruffled and feeding may stop completely. Sudden death is known to occur.

Diagnosis.—As in the case of *A. hamulosa.*

Treatment unknown.

Prophylaxis will obviously be difficult.

Several other species of *Acuaria* and related parasites occur in poultry and occasionally produce disease. Those described above are the commonest and most important.

Genus **Tetrameres** Creplin, 1846

This genus is related to the *Acuariidæ* and is remarkable for the fact that the mature female is almost spherical in shape, blood-red in colour and lies embedded in the proventricular glands of birds. The male is slender and its body cuticle is usually armed with four rows of spines; it is mostly found free in the lumen of the proventriculus, but it may follow the female into the gland temporarily for copulation.

T. americana Cram, 1927, occurs in the proventriculus of the fowl and turkey, and has been recorded from the United States and South Africa. Male 5-5·5 mm. long, female 3·5-4·5 by 3 mm. The latter is subspherical and deeply grooved in the regions of the longitudinal lines, while the anterior and posterior extremities project as conical appendages.

Life-Cycle.—The eggs are passed in the fæces of the bird and hatch after they have been swallowed by a suitable orthopteran insect (*Melanoplus femurrubrum*, *M. differentialis* and *Blattella germanica*). Infection of the final host occurs through ingestion of the infected intermediate host and, according to Cram, the males and females migrate into the proventricular glands, where they copulate. The males then leave the glands and die. The females contain eggs 35 days after infection, but reach their full size only after 3 months.

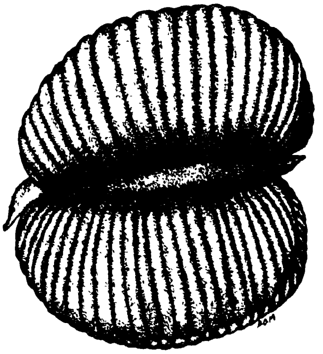

FIG. 154.—*Tetrameres americana*, FEMALE, LATERAL VIEW. (ORIGINAL.)

Pathogenicity, Lesions and Symptoms.—The worms suck blood, but the greatest damage is done when the young worms migrate into the wall of the proventriculus, causing marked irritation and inflammation, which may kill chicks (Cram). A toxic effect is also ascribed to this parasite. At autopsy the adult females can be seen from the outside of the proventriculus as dark objects in the depth of the tissues.

Treatment.—No suitable remedy is known.

Prophylaxis.—Birds confined on bare ground will be less liable to acquire the parasites than those running free. Young chicks particularly should be prevented from eating the intermediate hosts.

T. fissispina (Diesing, 1861) occurs in the duck, pigeon, fowl, turkey and wild aquatic birds and has a wide distribution. Male 3-6 mm. long, female 2·5-6 by 1-3·5 mm. The intermediate hosts are the water crustacea *Daphnia pulex* and *Gammarus pulex*, and in the final host the sexes are stated to copulate before the females migrate into the glands.

T. crami Swales, 1933, occurs in domestic and wild ducks in North America. Male up to 4·1 mm. long, females 1·5-3·5 by 1·2-2·2 mm. The intermediate hosts are amphipods: *Gammarus fasciatus* and *Hyalella knickerbockeri.* Severely infected birds are poor in condition.

Family PHYSALOPTERIDÆ

The cuticle usually forms a collar-like projection around the anterior extremity. The lips are simple and bear small teeth on their medial surfaces. A pharynx is absent.

Genus **Physaloptera** Rudolphi, 1819

P. præputialis von Linstow, 1889, occurs in the stomach of the cat and wild *Felidæ* in China, the East Indies, Africa and South America.

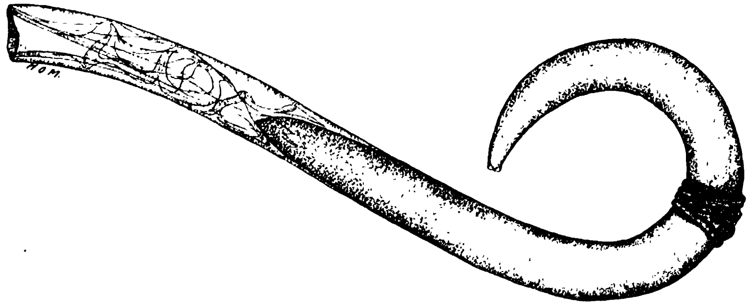

FIG. 155.—*Physaloptera præputialis*, FEMALE, LATERAL VIEW. (AFTER MÖNNIG.)

Male 13-40 mm., female 15-48 mm. long. The worms are stout, and the cuticle is posteriorly extended to form a sheath which projects beyond the caudal end of the body. In the fertilised female the vulva is covered by a conspicuous ring of brown cement material. Each lip bears at the middle of its free edge a set of three flattened, internal teeth, and externally to these a single conical external tooth of about the same height as the internals. The male tail bears large lateral alæ, joined together anteriorly across the ventral surface. There are four pairs of pedunculated papillæ, three sessile papillæ on the anterior lip of the cloaca and five pairs of sessile postcloacals. The left spicule is 1-1·2 mm. long and the right 0·84-0·9 mm. The eggs measure 49-58 by 30-34 μ.

Several other species of *Physaloptera* have been described from domestic animals. The following may particularly be noted:

P. rara Hall and Wigdor, 1918, known from the duodenum of a dog in the United States. **P. canis** Mönnig, 1928, occurs in the stomach of the dog and cat in South Africa. The eggs measure about 40 by 34 μ. **P. felidis** Ackert, 1936, occurs in the stomach and duodenum of cats in the United States, producing erosions at the points of attachment and sometimes a severe catarrhal gastritis with vomition and loss of condition. Ehlers* records a *Physaloptera* sp. from the stomach of badgers in the United States.

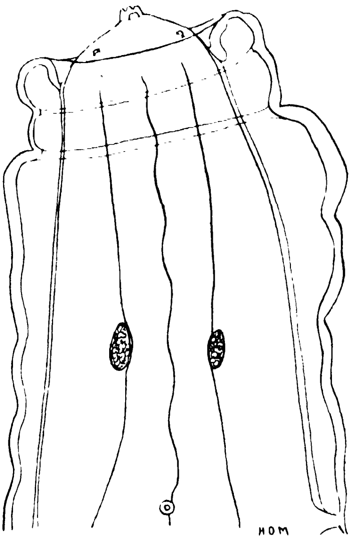

FIG. 156.—*Physaloptera canis*, ANTERIOR END, LATERAL VIEW. (ORIGINAL.)

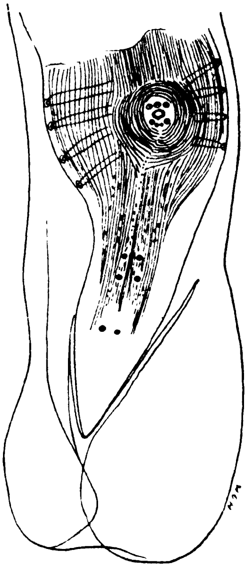

FIG. 157.—*Physaloptera canis*, HIND END OF MALE, VENTRAL VIEW. (ORIGINAL.)

Life-cycle unknown.

Pathogenesis and Symptoms.—The parasites, which occur in the stomach,

* *Journ. Amer. Vet. Med. Assn.*, 31 (1): 79-87. 1931.

are usually firmly attached to the mucosa, on which they feed, or they may also suck blood. Apparently they occasionally change their site of attachment and leave numerous small wounds which may continue to bleed. In this way the mucosa becomes eroded and highly inflamed. Ehlers states that the infected badgers were thin and quarrelsome, their fur was shaggy, and in bad cases the fæces had a tarry appearance. Later they stopped feeding and became paretic. The author received a large number of *P. præputialis* from a leopard which had apparently died of the infection. These worms contained a large amount of blood in their intestines.

Diagnosis may be made from the symptoms and the presence of Spirurid eggs in the fæces, which must be differentiated from those of *Spirocerca lupi.*

Treatment.—Ehlers was successful in expelling the worms from badgers by the administration of about 0·75 c.c. carbon bisulphide after fasting for 18-24 hours.

Prophylaxis.—Since the life-cycle is not known, no definite recommendation can be made. It is, however, probable that the intermediate hosts are coprophagous beetles or cockroaches, and steps should be taken to prevent the hosts from ingesting such insects.

Family THELAZIIDÆ

This family includes nematodes found in the conjunctival sacs of various animals. The lips are inconspicuous and the buccal cavity is small. The males usually have a large number of precloacal papillæ.

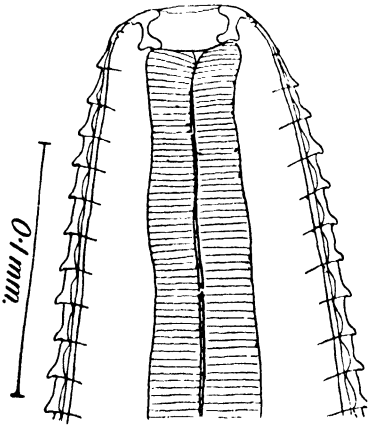

FIG. 158. — *Thelazia rhodesii*, ANTERIOR END OF FEMALE, LATERAL VIEW. (AFTER BAYLIS.)

Genus **Thelazia** Bosc, 1819

T. rhodesii (Desmarest, 1828) occurs in cattle, sheep, goats and buffaloes in Europe, Asia and Africa. Milky-white worms, male 8-12 mm., female 12-18 mm. long. The cuticle bears prominent transverse striations. The male has about fourteen pairs of precloacal and three pairs of post-cloacal papillæ. The spicules are 0·75-0·85 and 0·115-0·13 mm. long.

T. gulosa (Railliet and Henry, 1910) occurs in cattle in France and Sumatra.

T. alfortensis Railliet and Henry, 1910, occurs in cattle in France.

T. lacrymalis (Gurlt, 1831) occurs in the horse.

T. callipæda Railliet and Henry, 1910, occurs under the nictitating membrane of the dog in the Far East and has also been reported from the rabbit and man. Male 7-11·5 mm., female 7-17 mm. long. The cuticle has fine transverse striations. The male has five pairs and one single precloacal papilla and two pairs of postcloacals. The left spicule is about twelve times as long as the right. The vulva is situated in the œsophageal region. The eggs when laid contain fully developed larvæ which, soon after laying, extend themselves as well as the shells and so become sheathed larvæ.

T. californiensis Price, 1930,* occurs in sheep, deer, cat and dog in the United States.

Life-cycle unknown.

Genus **Oxyspirura** v. Drasche in Stossich, 1897

O. mansoni (Cobbold, 1879) occurs under the nictitating membrane of the fowl, turkey and pea-fowl in many countries. Male 10-16, female 12-19 mm. long. The cuticle is smooth and the pharynx roughly resembles an hourglass in shape. The male tail is curved ventrad and bears no alæ. There are four pairs of precloacal and two pairs of postcloacal papillæ. The left spicule is slender, 3-3·5 mm. long, and the right 0·2-0·22 mm. long and stout. The vulva is situated in the posterior part of the body and the eggs measure 50-65 by 45 μ.

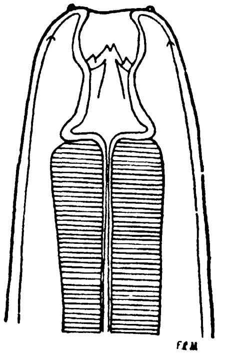

FIG. 159. — *Oxyspirura mansoni*, ANTERIOR END, VENTRAL VIEW. (FROM BAYLIS, AFTER YORKE AND MAPLESTONE.)

O. parvorum Sweet, 1910, described from the fowl in Australia, is possibly identical with the preceding species.

Life-Cycle.—The eggs of the parasite pass down the lachrymal ducts and out in the fæces of the bird. Fielding found in Australia that the intermediate stages develop in the cockroach *Pycnoscelus surinamensis*, and that fowls acquire the parasite by ingesting infected cockroaches. Similar results were also obtained in America. The larvæ escape from the intermediate host after it has been ingested and apparently wander up the œsophagus, pharynx and lachrymal duct to the eye, as they have been found there 20 minutes after cockroaches were fed to the chicks.

Pathogenesis, Lesions and Symptoms.—In many cases eyeworms have practically no pathogenic effect on the host, especially in the larger animals. In South Africa *T. rhodesii* is found frequently in calves without causing any lesions. The lesions of keratitis, ophthalmia and other conditions recorded as due to these worms were probably caused by other factors. In dogs conjunctivitis, lachrymation and photophobia are described as resulting from eyeworms. *O. mansoni* may produce lesions in the eyes of fowls, varying from conjunctivitis to a severe ophthalmia, blindness and complete destruction of the eyeball. It is possible that in such cases secondary infections with micro-organisms are involved.

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* Stewart, *Journ. Amer. Vet. Med. Assn.*, 96 (757): 486-489. 1940.

Diagnosis can be made definitely only by finding the worms in the eyes.

Treatment.—Dilute creolin solutions (1-2 per cent.) have been recommended for killing the worms. Mechanical removal of the parasites after administration of an anæsthetic to the eye is usually quite effective.

Prophylaxis.—Since the life-cycles of the *Thelazia* species are not known, no prophylactic measures can be recommended except general hygiene and control of cockroaches and dung beetles, which are probably the intermediate hosts. In the case of poultry cockroaches should be exterminated.

Family GNATHOSTOMIDÆ

The lips are large and trilobed, and on their medial surfaces the cuticle forms toothlike ridges which interlock with those of the opposite lip.

Genus **Gnathostoma** Owen, 1836

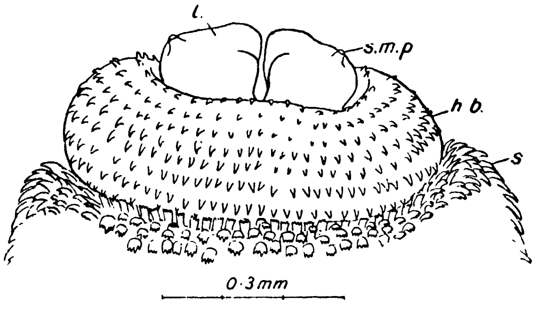

FIG. 160.—*Gnathostoma spinigerum*, ANTERIOR END, DORSAL VIEW. (AFTER BAYLIS AND LANE, IN *Proc. Zool. Soc.*)

h.b., Head-bulb; *l.*, lip; *s.*, spines of body; *s.m.p.*, submedian papilla.

G. spinigerum Owen, 1836, occurs in the stomach of the cat, dog, mink, polecat and several wild carnivora and as an erratic parasite under the skin of man. Male 10-25 mm., female 9-31 mm. long. There is a large head-bulb, containing four submedian cavities or " ballonets " which each communicate with a cervical sac. These cavities contain a fluid and apparently serve to fix the head in the tissues of the host by contraction of the cervical sacs and consequent swelling of the head-bulb. The cuticle of the head-bulb is armed with six to eleven transverse rows of hooks, while the anterior two-thirds of the body bears large, flat, cuticular spines with denticulate posterior edges. The ventral, caudal region of the male bears small spines and four pairs of large pedunculate papillæ as well as several smaller sessile ones. The left spicule is 1·1-2·63 mm. long and the right 0·4-0·8 mm. The vulva opens 4-8 mm. from the posterior end. The eggs are oval with a thin cap at one pole; they have a greenish shell ornamented with fine granulations, are passed in the one-cell or morula stage and measure about 69 by 37 μ.

*Life-Cycle.**—The eggs hatch in the water in 4 days or longer. The larvæ are sheathed and motile and die in a few days unless they are ingested by a *Cyclops*. In the latter they grow to 0·372 mm. long in 7 days or more, developing a definite cephalic bulb with four transverse rows of single-pointed spines, a pair of trilobate lips and two pairs of contractile cervical sacs. When the Cyclops is eaten by a fresh-water fish (*Clarias batrachus*, *Ophiocephalus striatus*, *Glossogobius giurus*, *Thereapon argenteus*) the parasites grow further to about 4·5 mm. long and become encysted. Such encysted forms, when fed to cats, become mature in the stomach wall in about 6 months. The young worms apparently sometimes migrate in the body of the final host, reaching the liver and other organs.

Pathogenesis, Lesions and Symptoms.—The young worms which pass through the liver cause much destruction of the tissues of this organ, leaving behind them characteristic yellow mosaic markings on the surface and burrows filled with necrotic material in the parenchyma. They also wander through other organs, including the mesentery and diaphragm, and they may enter the pleural cavity. Severe infections may therefore cause various disturbances in these organs. The adult worms penetrate into the wall of the stomach, producing cavities filled with a sanguino-purulent fluid. These cavities later develop into thick-walled cysts, each containing up to nine worms. The connection of the cysts with the stomach lumen may be very small and a similar minute canal may lead into the peritoneal cavity, providing the possibility for the development of peritonitis. Chandler considers this to be a very pathogenic and fatal parasite of cats, consistently killing its host. Cats with gastric tumours were found only at certain seasons, and they seemed to die out so that none were found at other times.

Diagnosis.—The eggs of the parasites are not always found in the fæces, hence diagnosis may be a difficult matter.

Treatment and Prophylaxis unknown.

G. hispidum Fedtchenko, 1872, occurs in the stomach of the pig in Europe and Asia. Larval forms cause creeping eruption in man (p. 194). Male 15-25 mm., female 22-45 mm. long. The whole body is covered with spines. The left spicule is 0·88-1·29 mm. long and the right 0·32-0·4 mm. The eggs measure 72-74 by 39-42 μ.

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* *Journ. Par.*, 23 (1): 115-116. 1937. *Philipp. Journ. Anim. Ind.*, 5 (4): 351-362. 1938.

The young worms migrate in the abdominal organs of the host, particularly the liver, where they may cause a hepatitis. The adults are found deeply embedded in the gastric mucosa, producing cavities which contain a reddish fluid and are surrounded by an inflamed area. Severe infections may produce a marked gastritis.

Order FILAROIDEA

These are long and relatively thin worms. As a rule the mouth is small and not surrounded by lips, and there is neither a buccal capsule nor a pharynx. The œsophagus has anterior muscular and posterior glandular portions. The male is frequently much smaller than the female and the spicules are unequal and dissimilar. The vulva is situated near the anterior extremity and fully developed larvæ are born. The worms live in the body cavities, blood or lymph vessels or connective tissues of their hosts.

The larvæ are known as microfilariæ. They are in some cases enclosed in a thin membrane or sheath which is apparently the very flexible egg-shell. They reach the bloodstream or the tissue lymph spaces of the host, whence they may be taken up by blood-sucking arthropods. In these intermediate hosts the larvæ develop to the infective stage and, passing into the body cavity, reach the proboscis of the arthropod. When the latter again sucks blood the larvæ break their way out and enter the final host, to complete their development.

In certain species of this group the microfilariæ show a definite " periodicity " with regard to their movements in the blood system of the final host, coinciding with the habits of the intermediate host concerned. For instance in *Wuchereria bancrofti* of man, which is transmitted by mosquitoes, the microfilariæ are much more numerous in the peripheral bloodvessels at night than during the day and they are said to have a " nocturnal periodicity." In *Loa loa*, also, a human parasite, which is transmitted by the Tabanid fly *Chrysops*, the reverse is the case and the larvæ are said to have a " diurnal periodicity." Several theories have been propounded to explain this phenomenon. The most probable explanation seems to be that the metabolism of the host differs during its periods of rest and activity and that this affects the microfilariæ. The periodicity of *W. bancrofti* can be reversed by working at night and sleeping during the day. Fülleborn has shown that the microfilariæ can live for long periods when they are injected into uninfected animals, and other authors record similar results. The organs of the host, therefore, do not seem to destroy them rapidly.

Family FILARIIDÆ

Genus **Dirofilaria** Railliet and Henry, 1911

D. immitis (Leidy, 1856) occurs in the dog, cat, fox and wolf in Southern Europe, India, China, Japan, Australia and North and South America. The worms live mainly in the right ventricle and the pulmonary artery, but have also been found in other parts of the body. Male about 16 cm., female about 25 cm. long. The worms are slender and white in colour. The œsophagus is 1·25-1·5 mm. long. The hind end of the male is spirally coiled and the tail bears small lateral alæ. There are four to six, usually five, pairs of ovoid papillæ, of which one pair is postcloacal, two pairs of finger-shaped papillæ lateral and posterior to the cloacal opening, and three to four pairs of small conical papillæ near the tip of the tail. The left spicule is 0·324-0·375 mm. long and pointed, the right is 0·19-0·229 mm. long and ends bluntly. The vulva is situated just behind the end of the œsophagus.

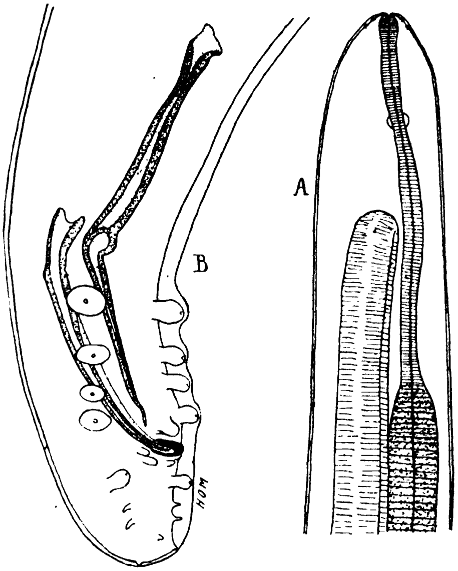

FIG. 161.—*Dirofilaria immitis.* (ORIGINAL.)
A, Anterior end of female, lateral view; B, hind end of male, ventro-lateral view.

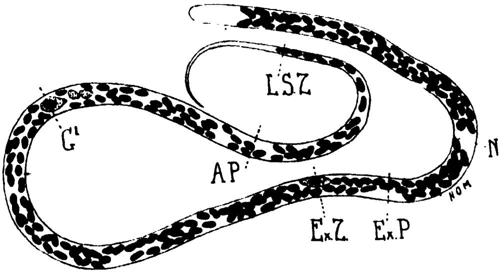

FIG. 162.—*Microfilaria immitis,* SHOWING "FIXED POINTS" FOR MEASUREMENTS. (ORIGINAL.)
A.P., Anal pore; Ex.P., excretory pore; Ex.Z., excretory cell; G^1., first genital cell; L.S.Z., last tail cell; N., nerve ring.

The microfilariæ occur in the blood, and some authors have recorded a slight nocturnal periodicity. The larvæ have a long, slender tail. Since different methods of fixation cause various degrees of contraction of the microfilariæ, it is customary to express the distance of certain fixed points from the anterior extremity as percentages of the total length. In this way accurate descriptions of the larvæ are obtained. The fixed points suggested by Fülleborn are the position of the nerve ring (N), the excretory pore (Ex.P.), the excretory cell (Ex.Z.), the first genital cell (G^1), the anal pore (A.P.) and the last nucleus or last tail cell (L.S.Z.). An elongate "central body" is seen with some methods of staining. The following table gives the measurements which have been recorded by various authors for the microfilariæ found in the dog:

	N.	*Ex.P.*	*Ex.Z.*	G^1.	*A.P.*	*L.S.Z.*	*Total Length.*
M. immitis (per cent.)	21·4	29·3	35·0	61·9	74·8	90·9	218–329 μ
	22·8	31·0	36·8	64·4	77·8	92·0	
M. repens (per cent.)	20·1	29·2	—	63·0	75·7	89·6	283–360 μ
M. dracunculoides ..	45 μ	66–70 μ	—	—	53–55 μ*	20 μ*	195–230 μ
M. grassii	—	—	—	—	—	—	567 μ
M. ochmanni	—	—	—	—	—	—	320 μ
M. reconditum ..	—	—	—	—	—	—	216 μ
M. auquieri	13–20 μ	—	—	—	—	—	58–102 μ
M. lewisi (per cent.)	22·47	31·82	35·52	59·82	78·82	91·05	140–212 μ

M. grassii does not occur in the blood, but in the subcutaneous lymph spaces. *M. ochmanni* is the only sheathed microfilaria described from the dog.

Life-Cycle.—The intermediate hosts are the dog flea, the cat flea and the human flea, as well as mosquitoes of the genera *Anopheles*, *Aedes*, *Culex* and *Myzorhynchus*. They ingest the microfilaræ with the blood of the host. Development in the fleas takes 120 hours, in the mosquito 240 hours, according to Summers. The infective larvæ then pass to the mouthparts of the intermediate host and are transferred to a new host during the act of biting. The parasites grow adult in the final host in about 8-9 months and may live several years.

Pathogenesis, Lesions and Symptoms.—The worms may be found at autopsy in the heart without having produced any lesions or symptoms during the life of the animal, while in other cases they may cause the death of their host. In some cases large numbers of worms are present. They may be the cause of an endocarditis or endarteritis or give rise to the formation of thrombi, and detached parts of the latter often cause embolism of branches of the pulmonary artery. When the worms themselves occur in these vessels thrombi may be formed which occlude the vessels and infarcts in the lung, pneumonic infiltration of the affected tissue or consolidation may develop, the latter being due to proliferation of the alveolar epithelium and the connective tissue. These lesions produce dyspnœa, a cough and a tendency to tire easily. The pulmonary lesions may, in chronic cases, give rise to venous stasis in the abdominal vessels and lead to ascites and œdema. Various other symptoms such as paresis of the hind-limbs, disturbance of vision, convulsions, rabiform symptoms and obesity have been described.

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* Distance from posterior extremity.

Diagnosis can be made by finding the larvæ in the blood. Stubbs and Live state that the larvæ are found in greater numbers and more easily in serum from clotted blood than in fresh blood. Larvæ lived in a refrigerator at 8° C. for up to 15 days and live larvæ were found in serum from a carcass 24 hours after death.

Treatment.—Wright and Underwood* recommend injections of Fouadin in the following doses for a dog of 10-15 kg. (22-33 lbs.): intramuscularly first 6 days each 1 c.c., then daily 1·5 c.c., every 7th day no treatment; intravenously 1st, 3rd, 5th days 1 c.c., 7th and 8th days 1·5 c.c., 9th, 10th and 12th days 2 c.c. The latter is more rapid and is suitable for dogs in good condition. Treatment is not well tolerated by dogs with infections of long standing which have organic heart disease, hyperplasia of walls of vessels in the liver and kidneys with cirrhosis and chronic interstitial nephritis. To such dogs smaller doses may be given, with careful observation and suspension of treatment on the appearance of adverse reactions. The microfilariæ disappear rapidly and the adults die off gradually after the treatment. Fouadin has a cumulative action and is excreted mainly in the urine. Liver damage may lead to guanidine retention and calcium therapy may be required in some cases.

Prophylaxis.—Infected animals are a source of infection and should be destroyed unless they are valuable. The healthy animals can be protected against the bites of mosquitoes by not letting them out towards the evening and in the early morning and keeping them in mosquito-proof kennels at night. Long-haired dogs are stated to become infected less frequently than short-haired individuals.

D. repens Raill. and Henry, 1911, occurs in the subcutaneous connective tissue of the dog in Italy, India and Indo-China. It is believed to be transmitted by *Stegomyia fasciata* and possibly also by *Anopheles maculipennis*. The microfilariæ are found in the subcutaneous lymph spaces. According to Bernard and Bauche the worms may cause pruritus without skin lesions.

Acanthocheilonema dracunculoides Cobbold, 1870, has been found in Africa in the peritoneal cavity of the dog and also in the aardwolf and the hyæna.

The other species of dog filariæ that are known from the adult worms or microfilariæ are rather rare.

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* *Vet. Med.*, 1929 (6): 234. 34.

Genus **Parafilaria** Yorke and Maplestone, 1926

P. multipapillosa (Condamine and Drouilly, 1878) (syn. *Filaria hæmorrhagica*) occurs in equines in eastern countries. Male 28 mm., female 40-70 mm. long. The anterior end of the body bears a large number of papilliform thickenings. The worms live in the subcutaneous and intermuscular connective tissue and produce subcutaneous nodules which appear suddenly, break open, bleed and then heal up. The condition is seen during the summer and disappears in winter, but may reappear the next summer. The life-cycle of the parasite is not known.

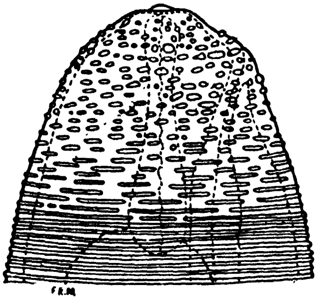

FIG. 163. — *Parafilaria multipapillosa*, ANTERIOR END OF FEMALE, LATERAL VIEW. (FROM BAYLIS, AFTER YORKE AND MAPLESTONE.)

P. bovicola de Jesus, 1934, causes hæmorrhagic nodules on cattle in the Philippines. Gulati describes similar lesions which are common during the summer in cattle in India. Injections of 100 c.c. 1 per cent. tartar emetic give good results and sometimes one injection suffices.

Genus **Onchocerca** Diesing, 1841

The species of this genus are elongate, filariform worms. They live in the connective tissue of their hosts, often giving rise to the formation of firm nodules in which they lie coiled up. The cuticle is transversely striated and, in addition, bears characteristic spiral thickenings which are usually interrupted in the lateral fields.

O. gibsoni Cleland and Johnston, 1910, occurs in cattle and the zebu in Australia, India, Ceylon, the Malay region and Southern Africa. The worms are usually found in nodules which occur especially on the brisket and the external surfaces of the hind-limbs and it is difficult to extricate complete specimens. The male is 30-53 mm. long, and the female is stated to measure 500 mm. or more in length. The tail of the male is curved ventrad; it bears small lateral alæ and 6-9 caudal papillæ on either side. The spicules measure 0·14-0·22 mm. and 0·047-0·094 mm. respectively. The microfilariæ are 0·22-0·35 mm. long and 3-4 μ thick and are not sheathed; the nerve ring is situated about 60-70 μ from the anterior end; the anterior and posterior portions of the larvæ which contain no nuclei are respectively 2·5-5 μ and 9-13 μ long; the body cuticle bears rather pronounced transverse striations.

Life-Cycle.—According to Buckley,* the intermediate host in Kuala-Lumpur is apparently the midge *Culicoides pungens.*

Pathogenesis and Lesions.—It seems that the parasites at first wander about in the connective tissue and later, when they come to rest, a nodule is formed around them. Mohammed,† who reviews the literature on this subject, thinks that the head of the worm becomes fixed and surrounded by fibroblasts and then successive portions of the body are drawn into the nodule, where they eventually lie coiled up and surrounded by fibrous tissue in different stages of development. The "worm nest" proper is surrounded by a fibrous tissue capsule which increases in thickness as the lesion grows older. The whole nodule may be up to 5 cm. in diameter, and it is ovoid or flattened in shape. The worm nest consists of tunnels containing the coils of the worm. The tunnel walls are composed of fibroblasts and loose fibrous tissue, infiltrated with polymorphonuclear leucocytes, especially eosinophiles, and sometimes giant cells are present. Microfilariæ are not frequent in the worm nests. In older nodules degeneration of the tissues and calcification of the worms frequently take place. The surrounding capsule consists of dense fibrous tissue which contains bloodvessels, clusters of leucocytes and lymph spaces. The walls of the vessels are much thickened and their lumina often obliterated. The microfilariæ are more frequent here and appear to wander out along the lymph spaces. Local thickenings of the skin, caused by the microfilariæ, have been described.

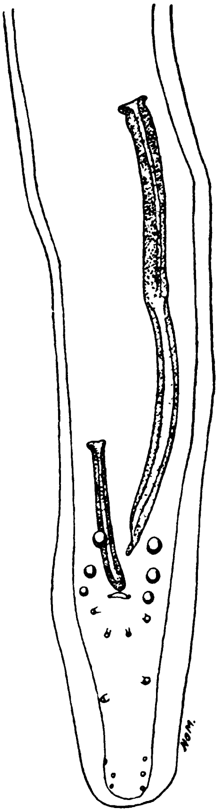

FIG. 164.—*Onchocerca gibsoni*, HIND END OF MALE, VENTRAL VIEW. (ORIGINAL.)

Symptoms and Significance.—Infected animals show no symptoms except the nodular swellings under the skin. The importance of the parasites is mainly that infected carcasses are not suitable for sale on most markets.

Diagnosis.—The microfilariæ are very rarely found in the blood, but they can be found in the subcutaneous lymph spaces. It is recommended that a piece of the skin be pinched up above the nodule, the surface epidermis shaved off with a sharp knife, and that the fluid which exudes be examined. Microfilariæ may be found even though no nodules are present.

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* *Journ. Helm.*, 16 (3): 121-158. 1938.

† *Ann. Trop. Med. and Par.*, 25 (2): 213-298. 1931.

Treatment.—No method of treatment is known.

Prophylaxis.—Since the habits of the vector would have to indicate the basis of prophylactic measures, no definite recommendations can be made, but it would be advisable to protect the animals as far as possible against the bites of blood-sucking insects.

O. gutturosa Neumann, 1910, occurs in the ligamentum nuchæ and other parts of the body of cattle. Male 2·9-3·9 cm., female 60 cm. or more. The microfilariæ are found in the skin of the host and, according to Steward,* are transmitted by *Simulium ornatum*, in which they develop to the infective stage in about 3 weeks.

O. cervicalis Railliet and Henry, 1910, occurs in the ligamentum nuchæ of the horse and mule in various countries. It has been incriminated as a cause of poll evil and fistulous withers, having been found in a number of cases of these diseases. It is transmitted by *Culicoides nubeculosus* according to Steward.†

O. reticulata Diesing, 1841, occurs in the connective tissue of the flexor tendons and the suspensory ligament of the fetlock, chiefly in the foreleg, of the horse, mule and donkey. The parasite may cause swellings and nodules in the tissues around it. According to Enigk, this species is identical with *O. cervicalis*.

Several other species of this genus are occasionally found in bovines and other domestic animals. None of the life-cycles are known and the parasites have little significance.

Genus **Elæophora** Railliet and Henry, 1912

E. poeli (Vryburg, 1897) occurs in the aorta of cattle and the zebu in Indo-China, the Malay Peninsula, Sumatra and the Philippines. Male 45-70 mm., female 80-300 mm. long. There are no lips and the œsophagus is very long. The tail of the male bears five to seven pairs of papillæ, two pairs being precloacal. The spicules measure 0·192-0·25 mm. and 0·12-0·132 mm. respectively. The uterus has four branches. The embryos are 0·34-0·36 mm. long, thick anteriorly and tapering posteriorly.

Life-cycle unknown. The male occurs in nodules in the wall of the aorta, while the female is fixed in the nodules with its anterior extremity, and the rest of its body hangs free in the lumen of the vessel. The site of the parasites is the thoracic portion of the aorta, often along the dorsal aspect near the openings of the vertebral arteries. The affected vessel is diffusely swollen. Its wall is thickened and less elastic than normal on account of the development of connective tissue. The intima is uneven, it contains fibrous tracks, and is raised by the nodules which lie between the intima and the media. The nodules measure 8-13 mm. in diameter and contain thrombi in process of organisation and the worms. It is stated that the infected animals show no symptoms.

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* *Par.*, 29 (2): 212-219. 1937.

† *Vet. Rec.*, 15 (52): 1563-1575. 1935.

Genus **Setaria**, Viborg, 1795

The worms of this genus are commonly found in the peritoneal cavity of ungulates. They are several centimetres long, milk-white in colour and taper especially towards the hind end, which is spirally coiled. The mouth is surrounded by a cuticular ring which bears dorsal and ventral and frequently also lateral prominences, giving a characteristic appearance to the worm. The tail of the male bears four pairs of precloacal and usually also four pairs of postcloacal papillæ. The spicules are unequal and dissimilar. The tail of the female may bear spines or a few large, conical projections, while in both sexes there is a pair of small appendages near the tip of the tail. The sheathed microfilariæ occur in the blood of the host.

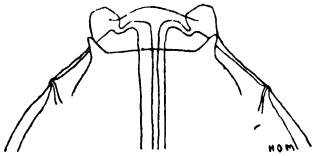

FIG. 165. — *Setaria equina*, ANTERIOR END, LATERAL VIEW. (ORIGINAL.)

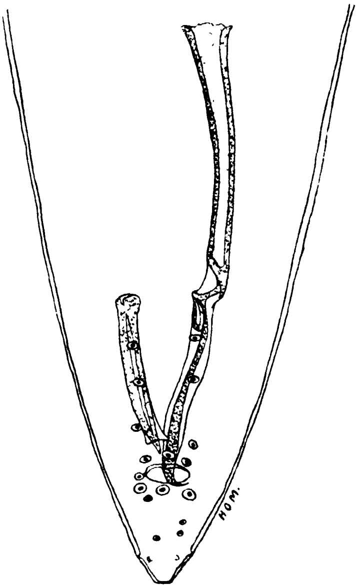

FIG. 166.—*Setaria equina*, HIND END OF MALE, VENTRAL VIEW. (ORIGINAL.)

S. equina (Abildgaard, 1789) is a common parasite of equines in all parts of the world. Male 50-80 mm., female 90-150 mm. long. There are large lateral and smaller, simple, dorsal and ventral peribuccal prominences. The left spicule is 0·63-0·66 mm. long and the right 0·14-0·23 mm. The tail of the female ends in a simple point. This worm is found in the peritoneal cavity and sometimes in the scrotum. It has also been recorded from the pleural cavity and the lungs of the horse and from the eye of cattle. It may produce a slight fibrinous peritonitis, but is usually of no consequence.

S. cervi (Rud., 1819) (syn. *S. labiato-papillosa*) occurs in cattle and various species of antelopes and deer. It has also been recorded from the eyes of horses. Male 40-60 mm., female 60-120 mm. long. The dorsal and ventral peribuccal prominences are notched. The spicules are 0·26-0·27 mm. and 0·1-0·12 mm. long respectively. The tail of the female has a spiny tip. This worm is transmitted by the stable fly *Stomoxys calcitrans*. It occurs in the peritoneal cavity of its host and is not pathogenic.

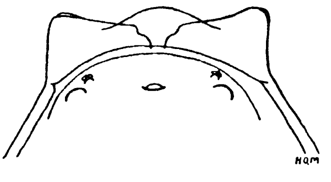

FIG. 167.—*Setaria cervi*, ANTERIOR END, LATERAL VIEW. (ORIGINAL.)

S. congolensis Railliet and Henry, 1911 (syn. *S. bernardi*) occurs in the peritoneal cavity of the pig.

Quite a number of species have been described from antelopes. One of them, *S. hornbyi* Boulenger, 1920, has also been found in sheep.

Genus Suifilaria Ortlepp, 1937

S. suis Ortlepp, 1937, was described from the pig in South Africa. The adult parasites live in the subcutaneous and intermuscular connective tissue and are not easily seen. The males are 17-25 mm. long, the females 32-40 mm. long and 0·15-0·17 mm. thick. The hind end of the male is spirally coiled; the spicules are unequal, the right measuring about 0·1 mm., the left 0·655-0·87 mm. long. The tail of the female ends abruptly and bears on its end a number of small tubercles. Eggs 51-61 by 28-32 μ.

Life-Cycle.—Unknown. The females appear to lay their eggs in the skin of the pig, because the skin of infected pigs shows numerous small, vesicular eruptions which contain the eggs of the worm.

Pathogenicity.—The worms may produce small, whitish nodules in the connective tissues which may be taken for young *Cysticercus cellulosæ* until they are more closely examined. Otherwise they do not affect the health of the pig, except for the fact that the skin vesicles containing the eggs eventually burst and may then become secondarily infected and develop into abscesses.

Genus **Stephanofilaria** Ihle and Ihle-Landenberg, 1933

S. dedoesi, Ihle and Ihle-Landenberg, 1933, occurs in the skin of cattle in Celebes and Sumatra. Male 2·3-3·2 mm., female 6·1-8·5 mm. long. The oral aperture is surrounded by a protruding cuticular rim which has a denticulate edge. Near to the anterior extremity there is a circular thickening which bears a number of small cuticular spines. Male spicules unequal. Female without anus.

Life-cycle unknown. It is suspected that the parasites are transmitted by blood-sucking arthropods.

Pathogenicity and Lesions.—Bubberman and Kraneveld* describe a verminous dermatitis, commonly known as " cascado," which is produced by these parasites and is probably identical with the " dermatitis verminosa pruriens bovis " of de Does (1907). Poor condition and high rainfall are predisposing factors and the incidence may be 90 per cent. in cattle. The lesions occur particularly on the sides of the neck, the withers, dewlap, shoulders and around the eyes. A number of small papules develop and coalesce to form a larger lesion covered with crusts; the hair falls out and the skin thickens, but it is rich in blood and lymph, which can be squeezed out readily. The lesion extends outwards while the centre becomes hard and covered with a thick, dry crust and may reach a size of 25 cm. diameter. Itching leads to rubbing, which may aggravate the lesion. The worms live in the epithelial layers of the skin and cause an inflammation of the rete Malpighii with proliferation and destruction of epithelial cells, destruction of hair follicles and skin glands and infiltration with small cells.

Diagnosis.—After removal of the crusts deep skin scrapings are made and the microfilariæ can be found in this material.

Treatment.—No remedy is known. Spontaneous recovery may occur.

S. stilesi Chitwood, 1934, is found in the United States and causes lesions resembling " cascado " mostly on the underside of the abdomen of cattle.

S. kaeli Buckley, 1937, causes lesions on the legs of cattle in the Malay Peninsula.

S. assamensis Pande, 1936, causes " hump sore " of cattle in India.

Family **Dracunculidæ** (syn. PHILOMETRIDÆ)

Genus **Dracunculus**

D. medinensis (Linnæus, 1758), the " guinea-worm," is a parasite of man which occurs especially in Southern Asia and Africa, but has been introduced into America, the West Indies and Fiji. It has also been found in the horse, dog, cattle and other animals, including the fox, raccoon and mink in North America. The male* is 12-29 mm. long. The female may be 100 to 400 cm. long and 1·7 mm. thick. The adult female lives in the subcutaneous connective tissue, and cutaneous swellings, which later become ulcers, develop around its anterior extremity. When these lesions come in contact with water the worm discharges a mass of larvæ which have to develop in a species of *Cyclops* to become infective for the final host. Infection of the latter takes place through drinking water which contains the infected *Cyclops* and the worms develop to maturity in about 1 year. Shortly before the parasite comes to the surface of the body the host may show symptoms such as urticaria, itching and a rise of temperature.

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* *Ned.-Ind. Bl. v. Diergeneesk.*, 45 (4): 239-278. 1933.

The most successful method of treatment known is the removal of the worm, which must be done carefully without breaking it. It is usually tied to a small stick and gradually rolled up in the course of a few weeks. According to Brumpt it can be easily extracted if a 0·1 per cent. solution of sublimate has been injected into the worm-tract the previous day. According to Moorthy an injection of 0·1 per cent. acriflavine assists in removal of the worm, while wells can be kept free of *Cyclops* for a month by adding perchloron and copper sulphate, respectively 3 lbs. and ½ lb. per 100,000 gallons of water (about 280 and 48 gm. respectively per 100,000 litres). The fish *Barbus puckelli* is stated to feed on *Cyclops* and the *Dracunculus* larvæ.

Order DIOCTOPHYMOIDEA

Family DIOCTOPHYMIDÆ

This group contains three genera in which the alimentary canal is attached to the abdominal wall by four longitudinal bands of suspensory muscles. The tail of the male bears a terminal, cup-shaped " bursa " without rays and there is a single spicule. The female has a single genital tube and the eggs have thick, pitted shells.

Genus **Dioctophyma** Collet-Meygret, 1802 (syn. *Eustrongylus*)

D. renale (Goeze, 1782) (syn. *Eustrongylus gigas*) is the largest nematode known and occurs in various countries in the kidneys and other organs of the dog, fox, otter, beech marten, pine marten, polecat, mink, weasel, other wild carnivores and the seal, and it has also occasionally been found in the pig, horse, cattle and man. The male measures up to 35 cm. by 3-4 mm., and the female up to 103 cm. by 5-12 mm. The worms have a blood-red colour. The spicule is 12-14·5 mm. long according to Lukasiak.† The eggs are barrel-shaped and the shells are pitted except

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* Moorthy, *Journ. Par.*, 23 (2): 220-224. 1937.

† *Arch. de Biol. de la Soc. de Sci. et de Lettres de Varsovie*, 3 (3): 1-100, 6 pl. 1930.

at the poles. They measure 71-84 by 46-52 μ and are not segmented when laid.

Life-Cycle.—The eggs are passed in the urine of the host and develop slowly in water, requiring 1-7 months according to the temperature. They do not hatch, but remain viable for 2 years. The rest of the life-cycle is not well known, but the infective stage probably occurs in fish, since the occurrence of the infection has been definitely associated with the eating of raw fish. Presumably the fish is a secondary intermediate host.

Pathogenesis and Lesions.—The right kidney appears to be invaded much more frequently than the left. The worms apparently enter the pelvis and destroy the parenchyma. Eventually only the capsule is left as a much-distended bladder, containing one or more worms and a hæmorrhagic fluid. If some of the kidney parenchyma is left, it may be partly calcified. Often a worm projects into the ureter. They may also wander down into the bladder and pass out through the urethra. In the abdominal cavity the worms may be found free or encapsulated, causing a chronic peritonitis with adhesions in various places. Frequently they lie between the lobes of the liver and destroy the surface of this organ. Small nodules containing eggs of the parasite may be found in the liver and the omentum. The worms have also been found in the pleural cavity.

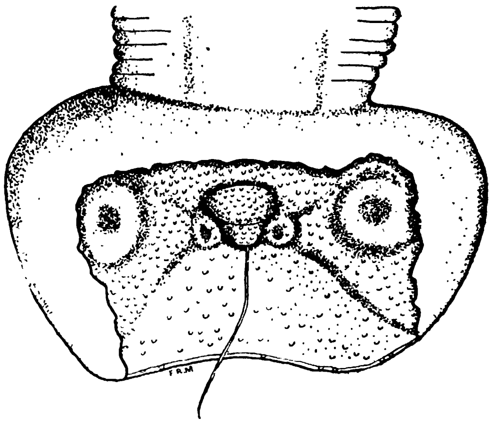

Fig. 168.—*Dioctophyma renale*, Posterior End of Male, Ventral View. (From Baylis, after Stefanski.)

Symptoms.—Frequently no symptoms are shown, since the normal kidney can serve the needs of the body. In other cases the infected animals grow thin and they may show signs of kidney trouble together with nervous symptoms. Retention of urine and death from uræmia may occur.

Diagnosis can be made by finding the eggs in the urine if the parasites occur in the kidneys.

Treatment unknown.

Prophylaxis.—The animals should be prevented from eating raw fish which may be infected.

Genus **Hystrichis** Dujardin, 1845

The species of this genus occur in aquatic birds. The anterior extremity is somewhat swollen and bears several rows of small spines.

H. tricolor Dujardin, 1845, occurs in the glands of the proventriculus of domestic and wild ducks, where it produces nodules and destruction of the tissues. The male is about 25 mm. long and the female up to 40 mm. The life-cycle is unknown.

CLASS NEMATOMORPHA

Mermithida and Gordiacea

These are long, thread-like worms, commonly called "horse-hair worms," white to dark brown in colour. In the adults the alimentary canal is partly atrophied. The worms live in water or moist soil, where they lay their eggs. The larvæ penetrate into various insects in which they live as parasites and they may grow to a considerable length. Eventually they leave their insect host, especially when the latter is moistened by rain or falls into water, and grow adult as free-living worms.

These worms may occasionally be swallowed with drinking water, but appear to do no harm. They will either be digested or passed through the alimentary tract. The older literature contains references to cases in which such worms lived for days or months in man or domestic animals and produced various symptoms, but such statements are probably quite erroneous. The worms are often found by laymen in drinking water and taken for possible parasites.

CLASS ACANTHOCEPHALA

The *Acanthocephala* are a group of parasitic worms usually considered as being closely allied to the *Nematoda*. They are commonly called "thorny-headed worms."

Morphology.—The body is in most cases cylindrical and is covered with a thick cuticle. Underneath this is a matrix without definite cell walls, but containing a number of nuclei and fine, branching vessels, of which the function is not known. Next follow circular and longitudinal muscles which line the body cavity.

An alimentary canal is absent. The worms feed like cestodes, by absorbing their nourishment through the body wall. Anteriorly the body bears an evaginable proboscis, which is a hollow, cylindrical or oval structure armed with transverse or longitudinal rows of recurved hooks and lies in a proboscis sac. Next to the proboscis sac a pair of elongate, hollow organs, the "lemnisci," project into the body cavity.

The proboscis is retracted by special muscles which are inserted in the body wall and it is evaginated by the contraction of the proboscis sac. The lemnisci are connected with the proboscis and probably secrete or store the proboscis fluid.

The excretory system consists of a pair of nephridia which discharge into the genital ducts.

From the proboscis sac a " suspensory ligament " runs backwards through the body cavity and provides attachment for the genital organs. The male has two testes which lie in a tandem position. The vasa deferentia unite to form an ejaculatory duct, and this opens through a " penis " which projects into an evaginable sac or " bursa " at the posterior extremity of the body. A group of cement glands or prostate glands are connected with the ejaculatory duct. They appear to secrete a substance which protects the vulva of the female after copulation.

In the female the ovary discharges its ova into the body cavity, where they appear to be fertilised and the embryo develops for some time, forming around itself a shell of three layers. The " uterine bell " is a special organ which swallows the eggs through an anterior opening and passes the mature eggs through into the vagina, while the immature ones are returned to the body cavity through a small pore situated posteriorly. The eggs contain larvæ which are provided with an anterior circlet of hooks.

Development.—As far as the life-cycles are known the eggs require to be ingested by an intermediate host, which is usually an arthropod. Whether vertebrates can act as intermediate hosts is uncertain. In some cases larval forms are found encapsulated in vertebrates, but these are probably secondary intermediate hosts or wrong hosts in which the immature parasites have become encysted, as in the case of some spirurid nematodes. The adult parasites occur chiefly in aquatic vertebrates, mainly fishes and birds.

Family ECHINORHYNCHIDÆ

Usually small worms with a cylindrical body. The proboscis hooks have a single, posterior root. The males have six cement glands.

Genus **Polymorphus** Lühe, 1911

P. boschadis (Schrank, 1788) (syn. *Echinorhynchus polymorphus* Bremser, *E. minutus* Zeder) occurs in the small intestine of the duck, swan, fowl, goose (?) and various wild aquatic birds. Male about 3 mm. long, female up to 10 mm. long. The worms have an orange colour when fresh. The cuticle is spiny anteriorly, and behind this region the body is constricted.

The proboscis has 16 longitudinal rows of 7-10 hooks each, which decrease in size posteriorly. The testes are oval, situated diagonally, and the cement glands are elongate. The eggs are spindle-shaped and measure about 110 by 19 μ. Their outer shell is thin, while the middle shell is thick and irregularly constricted at the poles. The embryo has a yellowish-red colour.

Life-Cycle.—The embryo develops in the crustacean *Gammarus pulex*, and possibly also in the crayfish *Potamobius astacus*. The final host acquires the infection by ingesting the infected intermediate host.

Pathogenesis and Symptoms.—The worms are located in the posterior part of the small intestine, where they penetrate deeply into the mucosa with their probosces. At the points of attachment small nodules can be seen from the peritoneal surface. The parasites produce anæmia and cachexia, and heavy infections can cause severe losses of ducks.

Diagnosis can be made by finding the eggs in the fæces.

Treatment.—No remedy is known. Carbon tetrachloride, tetrachlorethylene and nicotine preparations should be tried.

Prophylaxis.—The birds have to be kept away from water harbouring infected intermediate hosts.

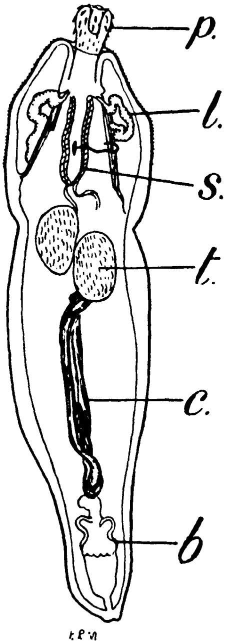

FIG. 169.—*Polymorphus boschadis*, MALE. (FROM BAYLIS, AFTER LÜHE.)

b., Bursa copulatrix; *c.*, cement glands; *l.*, lemniscus; *p.*, proboscis; *s.*, proboscis sac; *t.*, testis.

Genus Filicollis Lühe, 1911

F. anatis (Schrank, 1788) occurs in the small intestine of the duck, goose, swan and wild aquatic birds. Male 6-8 mm. long and white in colour, female 10-25 mm. long and yellowish. The male has an ovoid proboscis with 18 longitudinal rows of 10-11 hooks each and the anterior part of the body is armed with small spines. The lemnisci are long in both sexes. The female has a long, slender neck, while the proboscis is globular in shape and about 2-3 mm. in diameter. There are 18 rows of 10-11 hooks each arranged in a star-shaped pattern at the apex of the proboscis. The eggs are oval and measure 62-70 by 19-23 μ.

Life-Cycle.—The eggs are passed in the fæces of the host and the larval stage develops in the crustacean *Asellus aquaticus* (*Isopoda*) according to Szidat.* The final host acquires the infection by ingesting such isopods and the worms grow adult in about 4 weeks.

Pathogenesis, Lesions and Symptoms.—The parasites are situated in the middle portion of the small intestine and also further back in severe infections. While the male attaches its proboscis in the mucosa, the female worm pierces through the mucous and muscular layers of the wall, so that its proboscis comes to lie directly underneath the peritoneum. Szidat states that in some cases the peritoneum may even be ruptured, but peritonitis has not been seen. The parasites are obviously harmful; they cause emaciation and frequently the death of their hosts.

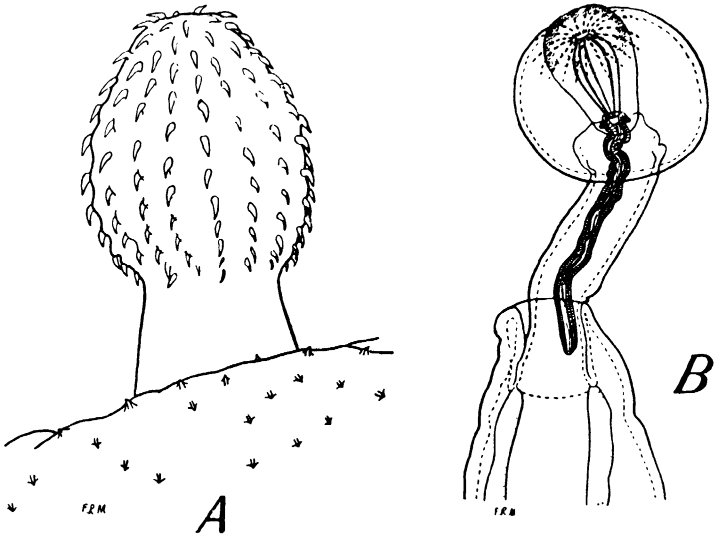

FIG. 170.—*Filicollis anatis.* (FROM BAYLIS, AFTER LÜHE.)
A, Anterior end of male; *B*, anterior end of female, less highly magnified.

Diagnosis can be made by finding the eggs in the fæces.

Treatment and Prophylaxis.—As in the case of *P. boschadis.*

Family GIGANTORHYNCHIDÆ

Usually large to medium-sized worms. The body is often laterally compressed. The proboscis is not retractile in the adult and its hooks usually have two roots.

Genus **Macracanthorhynchus** Travassos, 1916

M. hirudinaceus (Pallas, 1781) (syn. *Echinorhynchus gigas*) occurs in the small intestine of the pig and is widely distributed. The worms are usually more or less curved and have a pale reddish colour. The male is up to 10 cm. long and the female up to 35 cm. or even more and 4-10 mm. thick. The cuticle is transversely wrinkled. The proboscis is relatively small and bears about six transverse rows of six hooks each, which decrease in size backwards. The eggs measure 67-110 by 40-65 μ and have four shells, of which the second is dark brown and pitted.

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* *Arch. f. Geflügelk.*, 5 (3 4): 90-102. 1931.

Life-Cycle.—The eggs are passed in the fæces of the pig and are very resistant to cold and dryness, being able to live for several years in the open. They hatch when they have been ingested by the larvæ of certain beetles feeding in the manure or infected soil (*Melolontha vulgaris*, a number of dung beetles and the water beetle *Tropisternus collaris*). The young worm eventually becomes encysted in the body cavity of the insect. Pigs become infected by ingesting either the grubs or the adult beetles which harbour the infective stage of the worm. Development in the pig takes 2-3 months. A female lays about 260,000 eggs per day and lays for about 10 months.

Pathogenesis and Symptoms.—The parasites penetrate with their probosces deeply into the intestinal wall and may produce perforation and death from peritonitis. Apart from this possibility mild infections are not very harmful, but severe infections may cause slow growth or emaciation, which are very important in pigs.

Diagnosis can be made by finding the eggs in the fæces.

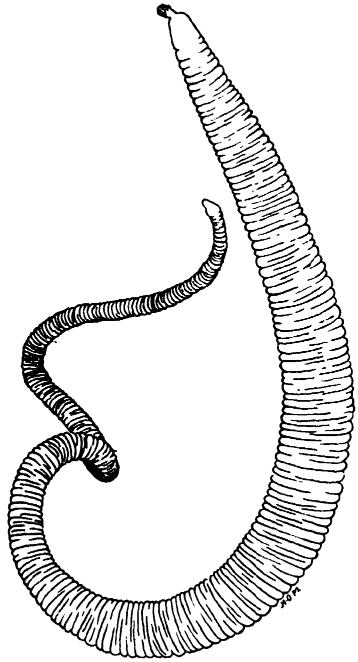

FIG. 171.—*Macracanthorhynchus hirudinaceus.* (× 1½.) (ORIGINAL.)

Treatment.—No satisfactory remedy is known. Wright and Raffensperger (1930), as well as others, tested numerous drugs, but with little success. Nicotine sulphate and carbon tetrachloride, especially mixtures of both, gave the best results.

Prophylaxis.—The pigs would have to be prevented from ingesting the larvæ or adults of the intermediate hosts. Where pigs are kept in sties or small runs regular removal and suitable disposal of fæces will assist in reducing the infection.

Genus Oncicola Travassos, 1916

O. canis (Kaupp, 1919) is a small parasite which occurs in the intestine of the dog in the United States. It has been suggested that the parasite may also occur in the coyote. According to Price* the male is

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* *Journ. Amer. Vet. Med. Assn.*, 22 (6). 1927.

6-13 mm. long and the female 7-14 mm., both sexes being 2-4 mm. thick. The shape of the body is roughly conical, tapering backwards, and it has a dark grey colour. The proboscis bears six transverse rows of six hooks each. The anterior hooks have the shape of a tænioid hook, while the posterior ones resemble rose thorns. The lemnisci are very long and slender. The testes are oval, tandem and situated in the anterior half of the body. The eggs are oval, brown in colour and measure 59-71 by 40-50 μ.

Life-Cycle.—Immature forms, about 4 mm. long, which are believed to belong to this species, have been found encysted in the connective tissue and muscles of the armadillo (*Dasypus novemcinctus*). Whether this animal is the only or a secondary intermediate host or a false final host is uncertain. Probably dogs could acquire the parasite by ingesting the immature forms which occur in the armadillo.

Pathogenicity.—The worms lie with their probosces deeply embedded in the intestinal wall, penetrating right through to the peritoneum. The parasite may possibly cause rabiform symptoms in dogs. Such symptoms were observed in a dog which harboured about 300 of the worms. It is known from the experiments of Calandruccio, who infected himself with another acanthocephalid (*Moniliformis moniliformis*), that the parasites may cause violent pains and ringing in the ears.

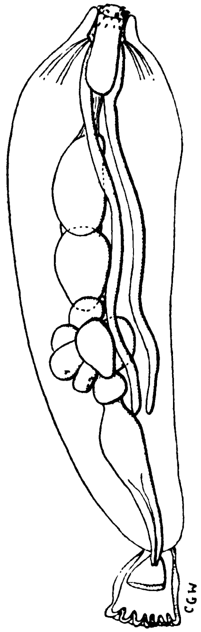

Fig. 172.—*Oncicola canis*, Male. (After Price.)

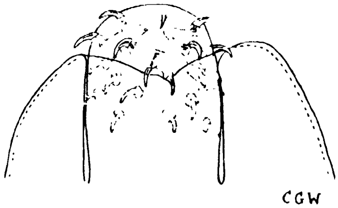

Fig. 173.— *Oncicola canis*, Anterior End. (After Price.)

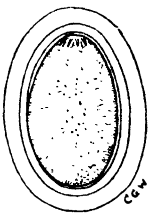

Fig. 174. — *Oncicola canis*, Egg. (After Price.)

Diagnosis can be made by finding the eggs in the fæces.

Treatment and Prophylaxis.—Unknown.

PHYLUM ANNELIDA

CLASS HIRUDINACEA

The *Hirudinacea*, or leeches, are not usually considered as " helminths," but are included here as parasitic worms in the wide sense of the term. They are soft-bodied and usually dorso-ventrally flattened worms with a true metameric segmentation. There are always 34 segments which are externally subdivided by transverse lines into 2-14 rings each. The anterior region is differentiated to form a head which bears a triangular antero-ventral sucker. The posterior 7 segments form a large sucker, except in one genus, and the anus is situated on the dorsal aspect of the hind end. The 9th, 10th and 11th segments form the clitellar organ which serves to secrete the cocoon in which the eggs are deposited.

In the *Gnathobdellæ* the anterior sucker contains the oral aperture, which is provided with three strong toothed jaws, while the *Rhynchobdellæ* have a protrusible proboscis. There is a short œsophagus and a stomach, which is usually provided with blind sacs for storage of ingested blood, followed by an intestine and a rectum. The body cavity is filled with a lacunar tissue. The excretory organs are segmentally arranged nephridia.

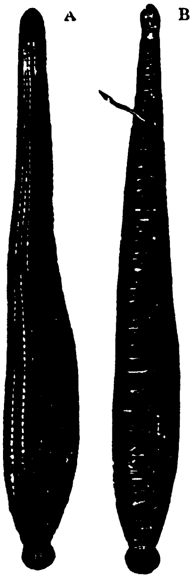

FIG. 175. — *Hirudo medicinalis.* (AFTER NEUMANN.)
A, dorsal; B, ventral view.

The worms are hermaphrodite. There are several to many testes which have a common duct on either side, and one pair of ovaries. The eggs are laid in cocoons secreted by the clitellum.

The leeches are occasional parasites. They feed on blood of various animals to which they attach themselves and drop off after having engorged. They have pharyngeal glands which secrete an anticoagulatory substance; this is injected into the wound made by the leech, and bleeding may continue for some time after the leech has dropped off. Leeches are vectors of certain trypanosomes of fresh-water fish.

The species of medical and veterinary interest belong to the *Gnathobdellæ*.

Genus **Hirudo** Linnæus, 1758

H. medicinalis Linnæus, 1758, is the leech formerly used for medicinal purposes. It is 8-12 cm. long and 1-2 cm. wide. The dorsal surface is greyish-green with six longitudinal reddish bands; the ventral surface is olive-green with a black band on either side. It occurs in Europe and North Africa and lives in marshes, small streams and pools of water. It is of little interest as a possible parasite, but occasionally animals may become infected.

Genus **Limnatis** Moquin-Tandon, 1826

L. nilotica (Savigny, 1820) occurs in Europe and North Africa in pools of water which contain plants. It is 8-10 cm. long and the body is soft. The dorsal surface is fairly dark brown or greenish and usually has several longitudinal rows of black spots. The ventral surface is darker than the dorsal and there is frequently an orange band on either side. The anterior lip has a longitudinal groove on its inner surface. The adult worms live at the bottom in the mud; the young leeches, however, occur near the surface and are very easily attracted by steps at the water's edge.

The young leeches can readily be swallowed by animals drinking in such ponds, and infection occurs chiefly in dry years when water is scarce. According to Iwanoff* this leech is very troublesome in Bulgaria; cattle, buffaloes, equines, sheep, dogs and pigs become infected.

Pathogenesis and Symptoms.—The parasites attach themselves in the pharynx and nasal cavities, where they may stay for days or even weeks. They suck blood, so that in severe infections anæmia and loss of condition may be produced. More serious is the frequent occurrence of œdemas in the affected areas. Blood or bloody froth may often be seen exuding from the mouth or nostrils of the animals. There is dyspnœa, and in severe cases the neck is extended and the mouth is held open. Œdematous swellings may be seen in the parotid and intermandibular regions. Death may be caused by asphyxia, and it may occur suddenly as a result of œdema of the glottis.

Diagnosis is made from the symptoms and by finding the parasites in the pharynx.

Treatment.—Iwanoff records very successful results from the injection of chloroform water. An elastic catheter is passed through the inferior nasal meatus and to the free end a 60 c.c. syringe containing the solution is attached. The latter is injected slowly while the catheter is revolved, the head of the animal being held in a horizontal position. In extreme cases tracheotomy may be necessary.

Prophylaxis.—The animals should be watered from clean troughs. Leeches in water can be killed by means of copper sulphate as applied for snails (p. 51).

L. africana occurs in West Africa. It is about 12 cm. long when fully extended. According to Sambon it is found attached in the nasal cavities of man, dogs and monkeys and frequently protrudes through the nostril. The leech is taken in while drinking infected water, and it may cause debility and marked local disturbances.

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* *Archiv f. wiss. u. prakt. Tierheilk.*, 62 (4): 429-437. 1930.

Genus **Hæmadipsa** Tennant, 1861

The species of this genus are small leeches, measuring about 2-3 cm. in length. They occur in tropical forests of Asia and South America and live on trees, shrubs and rocks, attaching themselves to passing animals and human beings. These leeches are very active and creep in even under tight-fitting clothing. Their bite is not painful, but the wounds may bleed for a long time.

SECTION IV

ARTHROPOD PARASITES

THE phylum **ARTHROPODA** contains those invertebrates that have jointed legs (*arthros*=a joint). The following classification, although rather obsolete and by no means ideal, is considered to be the most useful for the present purpose:

CLASS I.: **CRUSTACEA.**—Aquatic or more rarely terrestrial Arthropoda, usually breathing by means of gills, with two pairs of antennæ and numerous pairs of frequently biramous appendages on the thorax and abdomen. Includes crayfishes, crabs, shrimps, water-fleas, etc. This group is important in parasitology only because some species serve as intermediate hosts of helminths.

CLASS II.: **MYRIAPODA.**—Tracheate Arthropoda with numerous similar, pedigerous segments, one pair of antennæ and a pair of palpless mandibles. Includes millipedes (*Diplopoda*) and centipedes (*Chilopoda*); the bites of the latter may be poisonous.

CLASS III.: **INSECTA.**—The body of the adult is divided into three parts: (i.) A head which bears a single pair of antennæ; (ii.) a thorax which bears three pairs of legs and usually two pairs of wings; and (iii.) an abdomen which usually bears no appendages. Respiration is tracheal. The young are usually more or less different from the adults and a metamorphosis frequently occurs. It may be divided into the following orders:

ORDER 1: APTERA—originally wingless insects, covered with scales or hairs. Includes book-fish and springtails.

ORDER 2: ORTHOPTERA—two pairs of wings, the first leather-like, the second transparent and closing up like a fan. Mouth parts mandibulate. Metamorphosis slight. Includes locusts, stick and leaf insects and cockroaches.

ORDER 3: ANOPLURA—flattened dorso-ventrally, wings absent. Mouth parts mandibulate or suctorial. No metamorphosis. Includes biting and sucking lice.

ORDER 4: NEUROPTERA—two pairs of membranous, netted wings. Mouth parts mandibulate. Metamorphosis usually extensive. Includes dragonflies and termites.

ORDER 5: HYMENOPTERA—two pairs of membranous wings, the second pair smaller than the first and not folding. Mouth parts mandibulate and sometimes provided with a tubular process. Metamorphosis extensive. Includes bees, wasps and ants.

ORDER 6: COLEOPTERA—two pairs of wings; the first form hard "elytra" which meet perfectly in the mid-line and cover the second pair, which is membranous and folds up at several joints. Mouth parts mandibulate. Metamorphosis extensive. Includes the beetles.

ORDER 7: LEPIDOPTERA—two pairs of large wings covered with scales. Mouth parts suctorial. Metamorphosis extensive. Includes butterflies and moths.

ORDER 8: DIPTERA—one pair of membranous wings. Mouth parts suctorial, but vary greatly. Metamorphosis great. Includes flies and mosquitoes.

ORDER 9: SIPHONAPTERA—usually laterally compressed. Mouth parts suctorial. Wings absent. Metamorphosis extensive. Includes fleas.

ORDER 10: HEMIPTERA—two pairs of wings. Mouth perfectly suctorial. Metamorphosis usually slight. Includes bugs, plant lice and scale insects.

CLASS IV.: **ARACHNIDA.**—Air-breathing Arthropoda with the body usually distinguishable into two regions: a cephalothorax and an abdomen. The cephalothorax bears two pairs of jointed appendages, the cheliceræ and the pedipalpi, and four pairs of legs. Antennæ absent. Respiration by means of trachea or book-lungs. The following orders are of interest:

ORDER 1: SCORPIONIDA.—The body is composed of a cephalothorax and an abdomen; the latter has a broad anterior portion of seven segments and a narrow posterior portion of five segments with a terminal spine in the form of a sting. The pedipalpi are large and chelate (pincer-like). Includes scorpions.

ORDER 2: SOLPUGIDA.—The head, thorax and abdomen are separate. The pedipalpi are long and leg-like. Includes *Galeodes*, etc.

ORDER 3: ARANEIDA.—There is an undivided cephalothorax and an unsegmented abdomen which is usually soft and rounded. The cheliceræ bear poison glands, the pedipalpi are simple and small. Includes the spiders.

ORDER 4: ACARIDA—body not constricted into regions. Mouth parts usually adapted for piercing and sucking. The adult has eight legs, frequently arranged in two pairs on either side. Includes mites and ticks.

APPENDIX: **PENTASTOMIDA.**—Aberrant Arthropoda with a worm-like body and rudimentary mouth parts and no legs in the adult.

Morphology.—For the purpose of studying the morphology, especially external parts, an orthopteran (locust) is taken as type and other forms are dealt with comparatively.

The body consists of a number of *segments* which are remnants of the true segments of the *Annelida*, from which the arthropods are believed to have evolved. In the *Arthropoda* the segmentation is not true; the body cavity is continuous, forming a part of the vascular cavity or hæmocœle. Certain groups of segments form the head, the thorax and the abdomen. The body of the insect typically contains 20 segments (head 6, thorax 3, abdomen 11), but much fusion takes place, so that the segments are not all separately visible. In some of the *Arachnida* the segmentation has vanished completely.

The body is covered with *chitin*, a tough and flexible material, usually pigmented, secreted by an underlying layer of chitogenous cells; it is insoluble in most reagents. This " exoskeleton " bears outgrowths in the form of hairs and scales—sensory hairs are hollow and contain nerves. Internally there are prominences and even complicated structures, termed the " endoskeleton," to which muscles are attached. The primitive segment is supposed to consist of eight plates: two dorsal " terga," two ventral " sterna " and on either side two lateral " pleura "; these plates are joined together by more flexible portions of the chitinous covering. As a rule the dorsal and ventral plates respectively fuse together and the pleura are small or absent, as in the abdomen of the locust.

The *head* is a compact box of chitin and several regions can be recognised: the " vertex " which forms the dorsal portion, the " frons " or forehead, the " gena " or cheek, the " clypeus " which bears the upper lip, and the " gular region " to which the ventral portion of the neck is attached. The large compound eyes have numerous facets, each with a separate lens; their surface is hairy in some insects. The animal is said to be " dichoptic " if the eyes are well separated

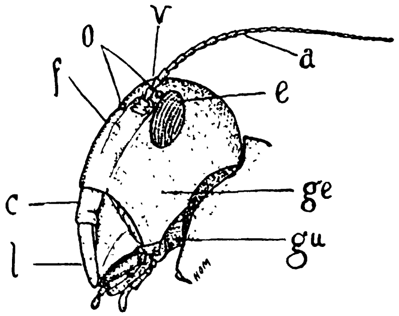

FIG. 176.—HEAD OF LOCUST, LATERAL VIEW. (ORIGINAL.)

a., Antenna; *c.*, clypeus; *e.*, eye; *f.*, frons; *ge.*, gena; *gu.*, gular region; *l.*, labrum; *o.*, ocelli; *v.*, vertex.

or "holoptic" if they are close together. The vertex usually bears a group of single eyes or "ocelli."

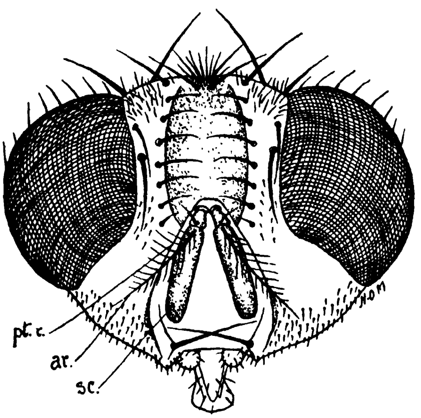

Fig. 177.—*Lucilia sericata*, Head, Anterior View. (Original.)

ar., Arista; *pt.r.*, ptilinal ridge; *sc.*, scape.

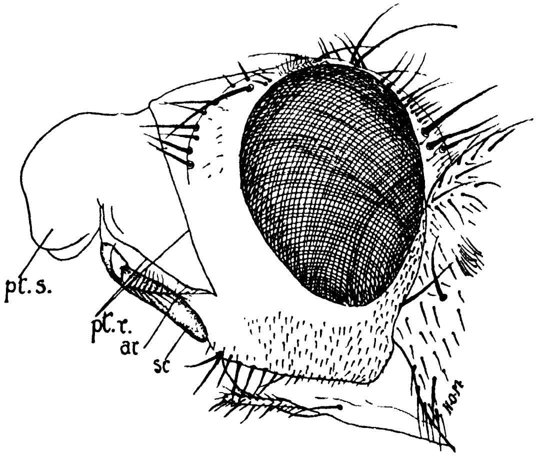

Fig. 178.—*Lucilia sericata*, Head of Fly just emerged from Puparium, showing Inflated Ptilinal Sac; Lateral View. (Original.)

ar., Arista; *pt.r.*, ptilinal ridge; *pt.s.*, ptilinal sac; *sc.*, scape.

The appendages of the head are the antennæ and the mouth parts. The *antennæ* are tactile organs, provided with sensory hairs, and are apparently sensitive to air currents. They also contain an "olfactory pit," possibly serving to perceive various odours. The antennæ consist of a variable number of segments and differ greatly in form in different arthropods. In the *Cyclorrhapha*, a section of the *Diptera*, the antenna consists of a "scape" and an "arista"; the scape has three segments, the distal one being the largest, and it bears the olfactory organs, while the arista is usually plume-like and is sensitive to air currents. The head of the *Cyclorrhapha* is further characterised by the presence of a horseshoe-shaped ridge, the "ptilinal suture," which runs transversely above the antennæ and downwards on either side of them. Along this suture the head capsule is invaginated in the form of a much convoluted membranous sac which functions only in the young fly. When the latter is ready to emerge from the puparium, it pushes out this "ptilinal sac" by inflating it, and thus breaks a circular piece off the anterior end of the pupal case. The sac is then gradually withdrawn and the ptilinal suture closes. The other section of the *Diptera*, the *Orthorrhapha*, have no ptilinal sac and emerge from the pupal case through a T-shaped crack on the dorsal aspect. Their antennæ also are usually simple.

The *mouth parts* of the locust, which eats solid food, are typically masticatory. Attached to the clypeus is the labrum or upper lip, which overhangs the mouth parts. On its inner surface it bears a small membranous structure, the epipharynx, which bears taste organs. The mandibles are a pair of strong, serrated and usually pigmented cutting organs. The first maxillæ are each composed of two basal segments, cardo and stipes, and the latter bears three structures: a medial lacinia, a lateral galea, and externally a jointed palp which has a sensory function. The second maxillæ have their basal segments fused together to form the submentum and the mentum. The latter bears on either side a jointed palp and two lobes, the glossa and the paraglossa, which may be fused to form a single structure. The second maxilla is also called the labium or lower lip, and it bears on its inner surface a small, membranous structure, the hypopharynx, on which the salivary glands open.

The mouth parts of the other insects can be compared to these simple structures in the locust. They show further development and specialisation in various directions.

In the *Diptera*, which take liquid food and have elongate, piercing and sucking mouth parts, the epipharynx and hypopharynx are strongly developed. The epipharynx is long and grooved ventrally, the hypopharynx long and flat, and the two together form a tube, the food canal. The distal opening of this tube is called the prestomum. The hypopharynx contains the salivary duct and brings the saliva to the prestomum. The labrum is fused with the epipharynx for strength. A sucking apparatus is formed proximally by the stomodæum (mouth cavity), which becomes chitinised and attached all round to the head capsule by muscles. The piercing and sucking actions are further assisted by air sacs in the head. The wound is made in the simpler blood-sucking

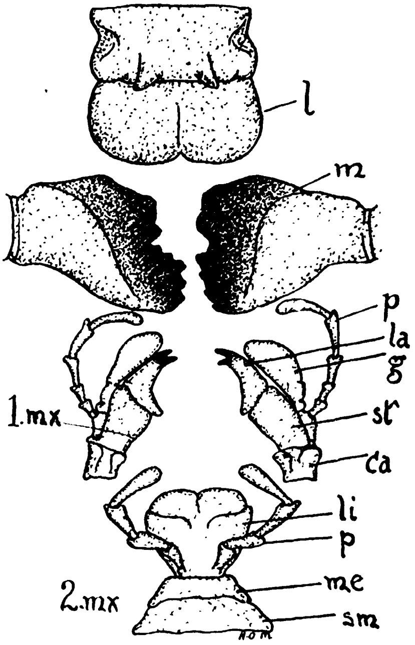

FIG. 179.—MOUTH PARTS OF LOCUST. (ORIGINAL.)

ca., Cardo; *g.*, galea; *l.*, labrum; *la.*, lacinia; *li.*, ligula; *m.*, mandible; *me.*, mentum; *p.*, palp; *sm.*, submentum; *st.*, stipes; 1 *mx.*, first maxilla; 2 *mx.*, second maxilla.

forms (*Orthorrhapha*) by the mandibles and first maxillæ, which are elongated and bear serrated tips; in the higher forms (*Cyclorrhapha*) these structures are absent and the function of cutting is performed by the second maxillæ, which have a special arrangement of teeth at the distal end. In all cases the fused second maxillæ form a large labium which bears the other mouth parts in a dorsal longitudinal groove, the labial gutter. The different types of dipteran mouth parts can now be considered.

The Orthorrhapha.—In *Tabanus* the proboscis is short and directed downwards under the head. The labrum-epipharynx is elongate; its concave ventral surface forms the dorsal wall of the food channel and its blunt distal extremity bears three small tubercles. The hypopharynx is long and slender and forms the ventral wall of the food channel. The mandibles are long blades armed with fine serrations on the medial edge distally. The first maxillæ form blades armed like rasps in their distal portions; these blades correspond to the galea of the locust. The palps of the first maxillæ are well developed and cover the proboscis on its dorsal aspect during rest. The labium is soft, strengthened ventrally by the chitinous mentum. Its dorsal longitudinal groove, the labial gutter, contains the other mouth parts. Distally the labium bears a pair of labella; these are oval lobes, flattened medially and convex laterally. Their medial walls, which are apposed during rest, but can be turned forward, are covered by a pseudo-tracheal membrane that bears a system of small channels serving to suck up fluid. The food channel leads posteriorly into the sucking apparatus which lies in the head. It is composed of two dilatations, the buccal cavity and the pharynx, both strengthened by plates of chitin that are controlled by muscles. The food is pumped up by rapid dilatations and contractions of these organs—the dilatations are produced by the muscles and the contractions by the inflation of the cephalic air sacs, which communicate with the respiratory system.

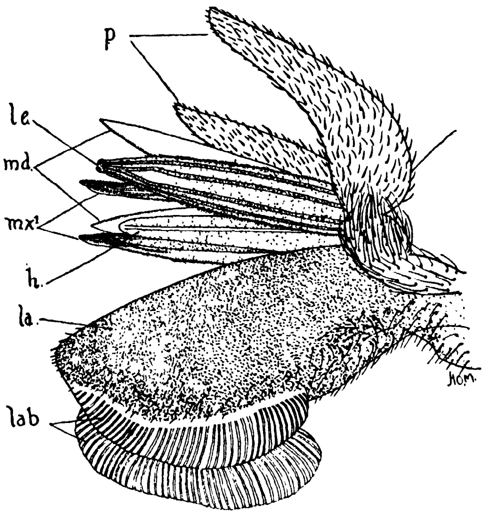

Fig. 180.—Mouth Parts of *Tabanus*. (Original.)

h., Hypopharynx; *la.*, labium; *lab.*, labella with pseudo-tracheal membrane; *l.e.*, labrum-epipharynx; *md.*, mandibles; *mx.*^{1}, first maxillæ; *p.*, palps.

In the *mosquito* the proboscis is very long and thin. The labrum-epipharynx is rounded and the hypopharynx is very slender, with a flexible tip. The mandibles are slender and armed distally, but their muscles are small and they do not seem to play an important part in producing the wound. In the males they are reduced or absent. The maxillæ are stouter than the mandibles and also armed at their tips. The labium is long and flexible; the mentum forms the ventral and lateral walls and curves inwards to strengthen the labial gutter. There are small labella, but these bear no pseudo-tracheal membranes.

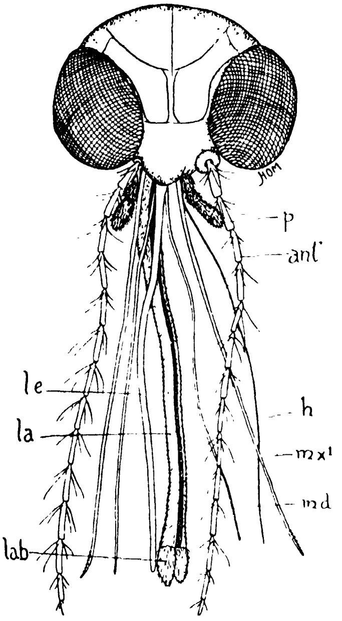

FIG. 181.—HEAD AND MOUTH PARTS OF A *Culex* FEMALE. (ORIGINAL.)

ant., Antenna; *h.*, hypopharynx; *la.*, labium; *l.e.*, labrum-epipharynx; *lab.*, labellum; *md.*, mandible; *mx.*^{1}, first maxilla; *p.*, palp.

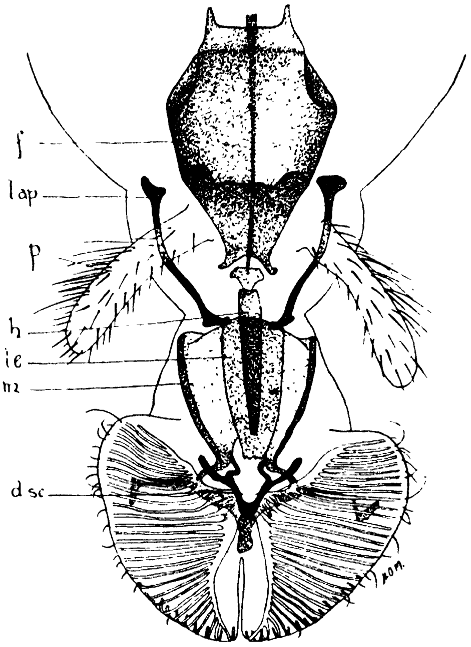

FIG. 182.—*Musca domestica*, MOUTH PARTS, DORSAL VIEW. (ORIGINAL.)

d sc., Discal sclerite; *f.*, fulcrum; *h.*, hypopharynx; *l.ap.*, labral apodeme; *l.e.*, labrum-epipharynx; *m.*, mentum; *p.*, palp.

The *Cylorrhapha* have lost the mandibles and first maxillæ; only the maxillary palps remain. The second maxillæ have become much more important. In the non-biting flies the labella are large and their pseudo-tracheal membranes strongly developed. In the biting forms teeth occur on the labella and these now produce the wound. The anterior wall of the head forms a conical projection, the rostrum, which bears the mouth parts. The whole projecting portion is now called the proboscis (in a wider sense) and consists of the rostrum, the haustellum and the labella; the latter two correspond to the proboscis of the *Orthorrhapha.*

In *Musca* the proboscis is completely retractile. The rostrum can be withdrawn into the head cavity and the haustellum and labella are concealed on the ventral side of the head. The rostrum is wide proximally, narrowing towards its junction with the haustellum, and bears the maxillary palps on its anterior surface. It contains air sacs and muscles which move the mouth parts, and a chitinous structure, the fulcrum, described as resembling a Spanish stirrup iron with the foot plate posterior and the toe at the lower end. The pharynx runs through the fulcrum; its posterior wall is formed by the foot plate and its anterior wall by a small plate of chitin which is attached by muscles to the anterior arch of the fulcrum. The haustellum comprises the labrum-epipharynx, the hypopharynx and the labium. The labrum is continuous with the anterior wall of the rostrum and is connected internally to two chitinous rods, the labral apodemes, through which its movements are controlled by muscles. The epipharynx and the hypopharynx are proximally continuous with the buccal cavity. The labium is strengthened posteriorly, and partly also laterally, by the chitinous mentum. Anteriorly it forms the labial gutter, strengthened along its edges by two rods of chitin which articulate distally with the labella. The labium is a hollow organ which contains muscles and a labial salivary gland; the latter is situated distally and secretes saliva on to the medial surfaces of the labella.

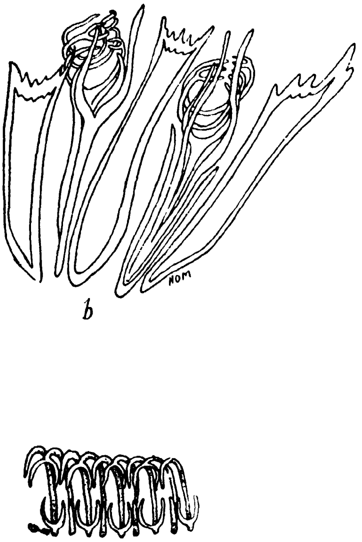

FIG. 183.—*Musca domestica*, CHITINOUS STRUCTURES OF PSEUDO-TRACHEAL MEMBRANE. (ORIGINAL.)

a, Chitinous supports of food channels; *b*, same at discal sclerite, with intervening tooth-like blades.

The labella are also hollow organs and their cavities are connected through that of the labium with the general body cavity or hæmocœle. Pressure of the hæmocœle fluid (blood) therefore causes the labella to expand and turn their medial surfaces forwards, so that they can be brought in contact with the food. Proximally the labella are supported and connected together by a chitinous ring, the discal sclerite, which surrounds the prestomum and articulates with the longitudinal rods of the labial gutter. Attached to the discal sclerite are also the pseudo-tracheal membranes which cover the medial surfaces of the labella and which bear each twenty to thirty grooves. Beginning at the periphery, these grooves converge towards the prestomum, the middle ones opening directly into it, while the dorsal and ventral grooves run first into larger collecting channels. Each groove is strengthened by a series of incomplete rings of chitin, standing closely side by side. The rings are bifid at one end and expanded at the other, and they are so arranged that the bifid and expanded ends alternate on either side of the groove. When the fly feeds the edges of the grooves are drawn together and the food is strained through the small openings which remain between the bifid and expanded ends of the rings. Under such conditions the house fly can swallow particles of only about 4 μ diameter, but it can swallow larger particles if the grooves are not so tightly shut, or particles of about 45 μ diameter if it separates the labella completely and sucks directly through the prestomum, although it is doubtful whether this is frequently done. These points are important in connection with the disease-transmitting powers of the fly.

Near the discal sclerite the rings become greatly altered, being more elongate and later Y-shaped with progressively longer stems. The last ones are attached to the discal sclerite. Between them, and apparently homologous to them, the discal sclerite bears a number of prestomal teeth which are unimportant in *Musca*, but become strongly developed in the blood-sucking flies. In the latter the pseudo-tracheal membranes disappear and the articulations of the labella become much stronger, in conformity with the increased activity of these organs. The proboscis is long, narrow and pointed in the blood-sucking flies and the labella are reduced in size. The muscles of the labium are more strongly developed and displaced backwards into a dilated portion of the labium known as the bulb. The labial gutter is strengthened by a keel and the whole haustellum is more rigid and no longer retractile, so that it is usually conspicuous.

In *Stomoxys* the rostrum is small, but the haustellum projects forward as a conspicuous proboscis. The mentum is wide proximally and forms the lateral and posterior walls of the bulb. Anteriorly it also strengthens the labium, which is a rigid structure. The labial gutter is strong distally, with a median keel. It contains the food channel, formed by the labrum-epipharynx and the hypopharynx, which are fused proximally into a complete tube. The labella are small, without a definite pseudotracheal membrane. They each bear four to six strong teeth that stand on a ridge of chitin and this in turn is connected to the discal sclerite. Between the teeth there is an interdental armature, consisting of one or more rows of slender blades, which strain the fluid sucked up by the fly.

The wound is made by the labellar teeth, which are drawn to and fro across the surface that has to be penetrated.

In *Glossina* the specialisation has gone still further. The proboscis is held forward during rest and is covered dorsally by the long palps. The bulb forms a marked proximal swelling, while the distal part of the haustellum is very slender. The labrum-epipharynx lies in the labial gutter, to which it is fixed by small interlocking denticles. The hypopharynx is very delicate and forms a closed food canal with the labrum-epipharynx, to which it is partly fused. The labial gutter is very strong and forms an almost complete tube in the middle of the haustellum. Distally it is continuous with the medial walls of the labella, since there is no discal sclerite. The labella are small and hardly wider than the

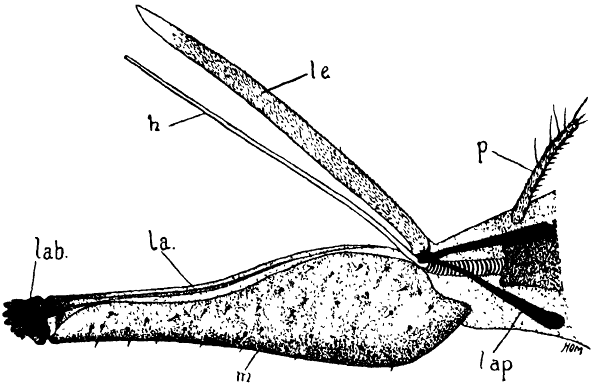

FIG. 184.—*Stomoxys calcitrans*, MOUTH PARTS. (ORIGINAL.)
h., Hypopharynx; *la.*, labium; *lab.*, labella with teeth; *l.ap.*, labral apodeme; *l.e.*, labrum-epipharynx; *m.*, mentum; *p.*, palp.

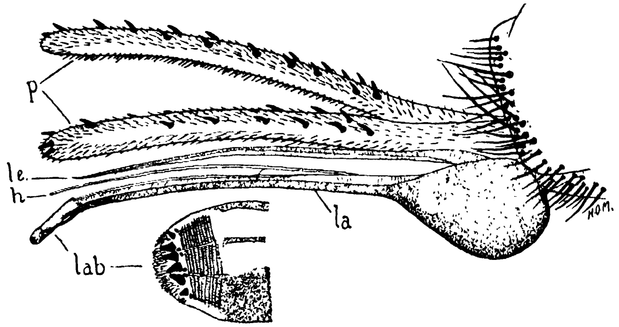

FIG. 185.—*Glossina pallidipes*, MOUTH PARTS. (ORIGINAL.)
h., Hypopharynx; *la.*, labium strengthened by mentum; *lab.*, labellum (enlarged figure, medial view, showing armature); *l.e.*, labrum-epipharynx; *p.*, palps.

haustellum. Their medial surfaces are divided by two horizontal grooves into dorsal, middle and ventral fields. Each field bears proximally a " rasp " consisting of about ten transverse ridges with fine, intervening horizontal ridges. Further on each field is provided with a transverse bar of chitin bearing two large teeth and two small ones at the sides. Distally to the teeth rows of small scales cover the surface; they are known as the " fans." The wound is made in the same way as in *Stomoxys* and the proboscis is inserted deeply. The labellar movements are produced by rapidly alternating muscular and respiratory activities, the latter forcing blood down into the labella to extend them.

Hippobosca shows an extreme specialisation. The main part of the proboscis can be concealed within the head in the resting position. The distal part is concealed by the palps which form a tube when they are closely applied together. Proximally there is a strong bulb and distally the labella are not clearly differentiated, but the wall of the proboscis has a membranous streak on either side which allows the distal part to move on the mentum and there is a set of strong teeth on either side of the prestomum. The labial gutter is covered by the labrum-epipharynx and contains the hypopharynx.

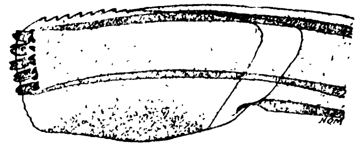

FIG. 186.—*Hippobosca rufipes*, DISTAL END OF PROBOSCIS, LATERAL VIEW. (ORIGINAL.)

In the *Hemiptera*, or bugs, the mouth parts have a piercing or sucking function. The labrum is small and immovable. The labium (second maxillæ) forms a complete tube with four joints and contains the piercing organs, which consist of the slender mandibles and first maxillæ. The proboscis is usually long and prominent and is held against the ventral surface of the body during rest. The salivary duct is equipped with a peculiar "syringe apparatus"; a dilatation of the duct forms the barrel and this contains a chitinous piston which is moved by muscles. The organ sucks up saliva from the duct and forces it through the proboscis.

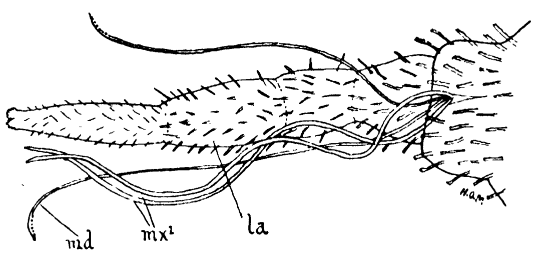

FIG. 187.—*Cimex lectularius*, MOUTH PARTS, DORSAL VIEW. (ORIGINAL.)
la., Labium; *md.*, mandible; *mx.*¹, first maxillæ.

In the *Siphonaptera*, or fleas, the ventral border of the head is sometimes armed with a row of stout spines, the genal comb. On either side of the head there is an antennal groove in which the small antennæ are concealed. The eye is not faceted and is deeply pigmented; in some species eyes are absent. Amongst the mouth parts all the original structures can be distinguished. The labrum-epipharynx is elongate and forms the dorsal wall of the food channel. The mandibles are long, thin blades beset with fine denticles; they are the principal cutting organs and also perform the work of the hypopharynx in forming the ventral wall of the food channel and in conducting the saliva to the wound. The hypopharynx is a short structure of little importance. The first maxillæ are broad, pointed blades, but they are short and do not function as cutting organs. Their palps are prominent. The second maxillæ, which are probably the palps, each consist of four joints and are not fused, but form a sheath for the piercing organs.

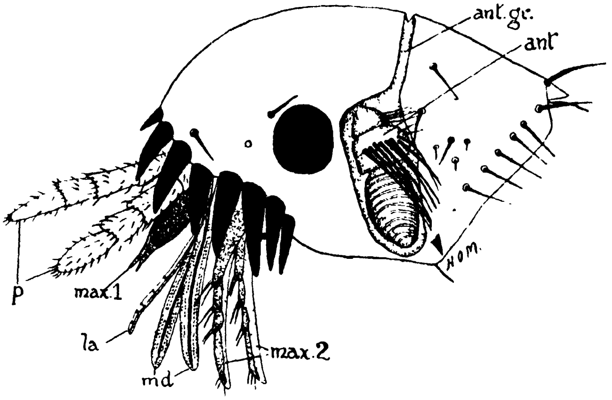

Fig. 188.—*Ctenocephalides canis*, Head, Lateral View. (Original.)
ant., Antenna; *ant.gr.*, antennal groove; *la.*, labrum-epipharynx; *max.*1, first maxilla; *max.*2, second maxillæ; *md.*, mandibles; *p.*, palps of first maxilla.

In the *Anoplura*, or lice, two definite groups can be distinguished: the sucking and the biting lice.

The *Siphunculata*, or sucking lice, have a conical, pointed head. The antennæ are inserted near the middle of the lateral borders; they are prominent and consist of three to five segments. The eyes are small and situated behind the antennæ. The mouth parts are small and their homology is not clear. In the resting position they are concealed within the head in a proboscis sheath. The oral aperture is surrounded by a circlet of small teeth, by means of which the louse fixes its mouth to the skin of the host before it begins to suck.

The *Mallophaga*, or biting lice, have a large, flat head, frequently rounded anteriorly. The mouth parts are situated on the ventral surface and are of the mandibulate type.

The *Acarida*, mites and ticks, have an oval, flat body without distinct segmentation. Sometimes a cephalothorax is marked off from the abdomen. The cephalothorax has an anterior notch, the camerostoma, into which is inserted the basis capituli or capitulum, a small chitinous structure which bears the mouth parts or rostrum. On the antero-lateral margins of the capitulum stand the four-jointed palps. The mouth parts consist of a dorsal pair of mandibles which lie in mandibular sheaths; the sheaths are covered with numerous fine denticles. Each mandible consists of a cylindrical shaft which projects for a considerable distance into the body of the tick. Distally it bears a pair of toothed digits that can be moved by muscular action. The maxillæ, absent in the *Ixodoidea*, or ticks, are narrow blades of chitin which are shorter than the mandibles and lie ventral to these (the mandibles and maxillæ are not homologous to those of the insects). Ventrally there is a club-shaped or spatulate organ, the hypostome, which consists of two parts closely applied together. It bears regular rows of small and large denticles. In some mites the digits of the mandibles are claw-like in the female, while in the male they bear structures that are thought to assist in fertilisation.

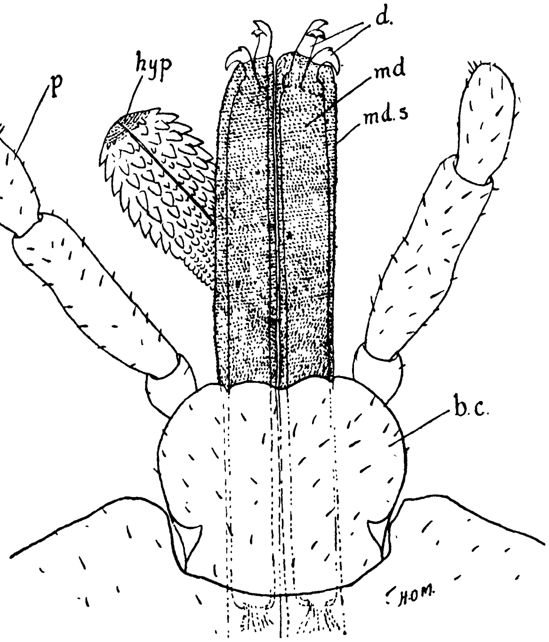

Fig. 189.—*Amblyomma hebræum*, Anterior End, Dorsal View. (Original.)
b.c., Basis capituli; *d.*, digits of mandible; *hyp.*, hypostome, twisted to show its ventral surface; *md.*, shaft of mandible; *md.s.*, mandibular sheath; *p.*, palp.

The *thorax* consists of three segments, the pro-, meso- and meta thorax. The wings are borne on the meso- and metathorax and in *Diptera* on the mesothorax; the latter therefore becomes predominant; and three transverse grooves divide it into separate portions called the præscutum, scutum and scutellum. The wings are not true appendages, but are outgrowths of the body wall, formed from buds that arise in the pupal stage. The wing is therefore a double membrane and contains trachæ, which are known as the veins. The anterior border of the wing is more or less straight; the distal extremity is called the apex and the posterior border is gently rounded and frequently notched proximally so that several lobes are formed. These are named, from the apical side inwards, the anal lobe, the alula, the antisquama and the squama. The latter is usually a fairly conspicuous, more or less circular membrane, located against the body of the fly. The coloration of the wings and the presence of hairs or scales are important in systematic work. Most important is the venation. In the lower forms a number of veins run out from the base to the apex and to the posterior border. In the higher forms the number of veins is reduced and they are connected by transverse veins. In strong fliers the veins are as a rule crowded towards the anterior border. Various systems of nomenclature for the veins have been proposed. In Comstock and Needham's system there are supposed to be six main veins which may be branched; they are known as the costa, subcosta, radial, median, cubital and anal. According to another system they are called costal, subcostal, first, second, etc., longitudinal veins. The spaces between the veins are called cells and are named after the veins immediately anterior to them.

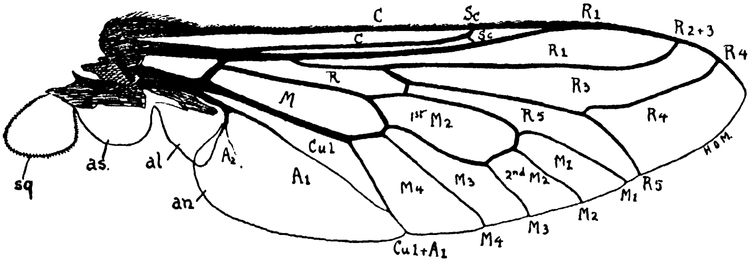

FIG. 190.—*Tabanus*, WING SHOWING VEINS AND CELLS. (ORIGINAL.)
A., Anal; C., costa; *Cu.*, cubital; M., median; R., radial; *Sc.*, subcosta; *al.*, alula; *an.*, anal lobe; *as.*, antisquama; *sq.*, squama.

In the *Diptera* the second pair of wings is frequently present in the form of rudiments, called halteres or balancers; they stand on cushion-like thickenings and are composed of a stalk which bears distally a circular, membranous disc containing numerous nerve cells and sense organs.

The *legs* have five main segments called the coxa, trochanter, femur, tibia and tarsus. The latter usually has five segments and bears terminally a pair of claws and between them a bilateral cushion of glandular hairs, the pulvillus. There may also be a small median organ, the empodium, which contains nerve cells. In the *Acarida* suckers are frequently present between the claws.

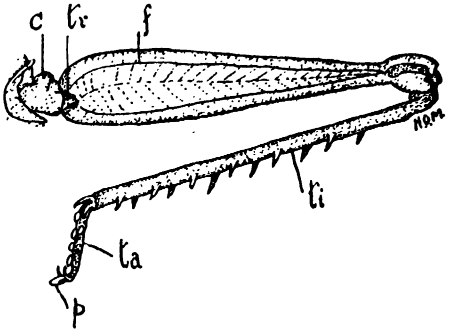

FIG. 191.—LEG OF A LOCUST. (ORIGINAL.)
c., Coxa; *f.*, femur; *p.*, pulvillus; *ta.*, tarsus; *ti.*, tibia; *tr.*, trochanter.

The *abdomen* is usually simple and clearly segmented, but in the *Pupipara* and the *Acarida* the segmentation is lost. The posterior segments are involved in the formation of the external genitalia which assist in copulation and oviposition. These organs show great variation in different forms, but those of the male, the hypopygium, usually comprise a pair of hook-like structures or claspers and sometimes also a penis which has a sheath. In the female there is an ovipositor which can be drawn together like a telescope and lies within the body during rest.

The *muscles* consist of transversely striped fibres which are capable of very rapid action; it is stated that the wing muscles of the fly perform over three hundred contractions per second. The wings are moved up and down only, but since the anterior border is more rigid than the posterior, the wing is flexed and comes to stand at an angle.

The *respiratory system* consists usually of a system of branching tubes, the tracheæ, which open through spiracles or stigmata at the sides of the body. The tracheæ are composed of a thin layer of chitin strengthened by spiral thickenings and secreted by special chitogenous cells. They end in air sacs with very delicate walls. Normally there is a pair of spiracles to each segment, but they are usually reduced in number, and there are none in the head and the prothorax. They are bordered by a thick rim of chitin which bears bristles and they open into a vestibule which contains a valve controlled by muscles. The respiratory movements are produced by muscular contractions and elastic distensions of the body wall.

The *alimentary canal* consists of a stomodæum, a mesenteron and a proctodæum. Of stomodeal origin are the buccal cavity with the salivary glands, the epi- and hypopharynx, the pharynx, the proventriculus or gizzard, and the crop, or œsophageal diverticulum or food reservoir. The mesenteron forms the mid-gut. Proctodeal are the intestine or hind-gut and the rectum, together with the Malpighian tubes and the papillæ of the rectum. A crop is present in most *Diptera* and it is joined to the œsophagus by a narrow tube. In mosquitoes it is represented by three thin bags. The gizzard is present in insects that eat solid food, like the locust, and it contains a complicated set of teeth on its internal surface. The salivary glands are paired and have long ducts, which later join to form a common duct. The Malpighian tubes probably have an excretory function. An œsophageal valve may be present and in the *Cyclorrhapha* the proventriculus is a compact, spherical structure which functions as a valve. In the *Cyclorrhapha* and some other insects there is a delicate, tubular peritrophic membrane within the alimentary canal, extending from the mid-gut to the rectum. Its posterior end is not attached to the intestinal wall. It separates the food from the wall of the intestine, but osmosis takes place through it. In the *Acarida* the mid-gut has several diverticula, which are blind sacs capable of great distension.

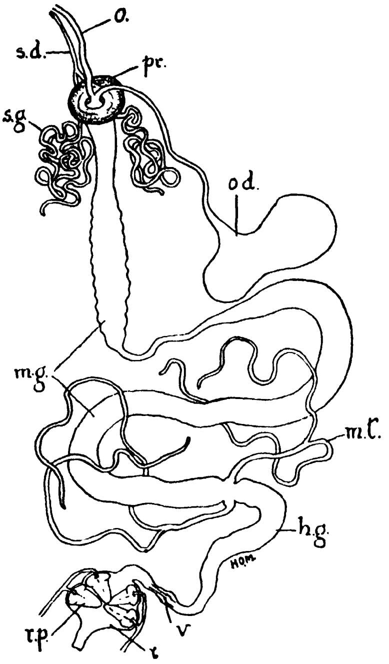

FIG. 192.—*Lucilia sericata*, ALIMENTARY TRACT. (ORIGINAL.)

h.g., Hind-gut; *m.g.*, mid-gut; *m.t.*, Malpighian tubules; *o.*, œsophagus; *o.d.*, œsophageal diverticulum; *pr.*, proventriculus; *r.*, rectum; *r.p.*, rectal papilla; *s.d.*, salivary duct; *s.g.*, salivary gland; *v.*, valve.

The *vascular system* comprises a dorsally situated heart, an aorta and the general body cavity or hæmocœle. The heart is a tube surrounded by pericardial cells, and its lumen is divided into a number of compartments by valves which allow the blood to pass forward only. Each compartment opens into the hæmocœle through a pair of ostia. Anteriorly there is an aorta which carries the blood to the head, whence it enters the hæmocœle and bathes all the organs. The blood is a viscid fluid and contains few cells.

The fat-body consists of numerous cells laden with fat and lies in the body wall, lining the hæmocœle and surrounding all organs. It is especially large in recently emerged adults, pupæ and mature larvæ, and may hang into the body cavity in large masses.

The *nervous system* consists of a circumœsophageal commissure with ganglia and a double ventral chain of ganglia from which nerves are given off. This ventral nerve chain originally had a pair of ganglia to each segment, but usually concentration occurs by fusion of the ganglia, especially in the thorax. In some cases the thoracic and abdominal ganglia may all be fused together.

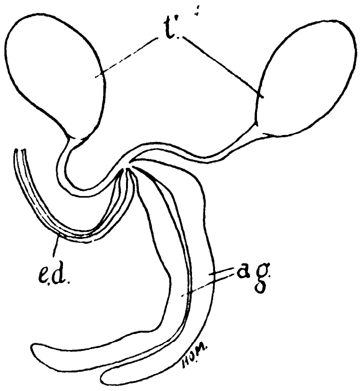

Fig. 193.—*Lucilia sericata*, Male Genital Organs. (Original.)

a.g., Accessory glands; *e.d.*, ejaculatory duct; *t.*, testes.

Reproductive System.—The male has two testes, each with a vas deferens forming distally a vesicula seminalis and then fusing to form a common duct. A penis with a sheath and other accessory structures are frequently present. The female has two ovaries, which consist of groups of ovarian tubes, all arising from an apical filament. The ducts unite to form a common duct which bears the receptaculum seminis and ends in the ovipositor. Accessory glands are usually present. Some insects are oviparous, others viviparous or larviparous, and some even pupiparous, like *Glossina* and the *Pupipara*, which give birth to larvæ that are ready to pupate. In these latter forms the larvæ are nursed in the common portion of the oviduct, the uterus, which is provided with so-called " milk glands " that secrete a milky fluid through a teat to which the mouth of the larva is applied. Only one larva is born at a time. The larva usually lies with its stigmatic plate at the vulva of the fly and is thus able to breathe.

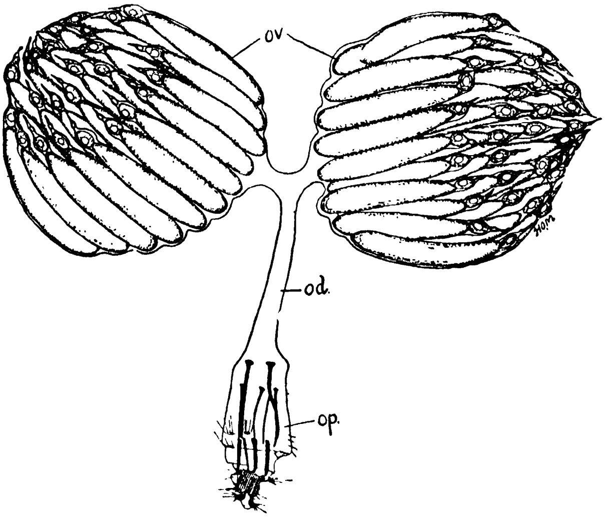

Fig. 194.—*Lucilia sericata*, Female Genital Organs. (Original.)

od., Oviduct; *op.*, ovipositor, contracted; *ov.*, ovaries.

Development.—As a rule the eggs consist of a large mass of yolk surrounded by the cytoplasm, which undergoes segmentation and the body of the embryo is formed around the yolk. The rate of development is greatly influenced by the temperature, and sometimes the presence of a fair amount of moisture is absolutely essential, else the eggs may remain dormant. In some cases the young arthropod which hatches from the egg resembles the adult; in other cases it differs from the adult only in size and minor features, as in the case of locusts or ticks, or there is a very marked difference, and definite stages, termed the larva, pupa and imago, are seen. Ecdyses always occur, and the different stages separated in this way are called " instars." The larvæ of the *Lepidoptera* are known as " caterpillars " and those of the higher *Diptera* are called " maggots." The *Acarida* have three stages, known as the larva, nymph and imago. The larva has three pairs of legs, while the nymph and imago have four pairs; the nymph has no genital apertures.

Some insect larvæ feed on solid particles and have masticatory mouth parts and a definite head—they are said to be " eucephalous." Others have a less distinct head—" hemicephalous "—while the forms which live in rich food material like carcasses need no special mouth parts or head and are said to be " acephalous."

Most dipteran larvæ cast their skins three times. In the *Orthorrhapha* the last larval skin is usually cast at the moment of pupation and the pupa, which may be active, is said to be " obtectate." In the *Cyclorrhapha* the larval skin remains as the pupal covering or puparium which hardens, so that the pupa is not mobile—it is " coarctate."

A. DIRECTLY POISONOUS ARTHROPODA

Although the poisonous nature of some arthropods is popularly much exaggerated, there are a number of forms that can be poisonous to man and animals in various ways.

1. *Piercing or biting forms* inject a poisonous or irritating substance into a wound made by their mouth parts or poison claws—*e.g.* spiders, mosquitoes, centipedes.
2. *Stinging forms* inject a poison by means of a sting situated at the end of the abdomen. Such a sting is frequently a modified ovipositor—*e.g.* bees, scorpions.
3. *Nettling forms* have hairs or scales which possess irritating properties —*e.g.* certain caterpillars.
4. *Cryptotoxic forms* contain irritant or poisonous body fluids—*e.g.* the Spanish fly.

Myriapoda.—The millipedes (*Diplopoda*) are not poisonous, but some of the large tropical species are stated to eject poisonous or pungent fluids from cutaneous glands when they are irritated. The centipedes (*Chilopoda*) have the first pair of legs modified as claws which contain poison glands. These are insectivorous animals and they use the poison claws to stun their prey. The smaller forms can at most cause a painful local reaction in larger animals or man, but the large forms, *e.g.* the tropical *Scolopendra gigantea*, are able to cause death. The *Diplopoda* are circular in transverse section and have two pairs of legs to most segments. The *Chilopoda* are flattened dorso-ventrally and have a single pair of legs per segment.

Insecta : (1) *Piercing or Biting Forms.*—There are many forms that may inflict painful bites on human beings, like certain water-bugs and the assassin bugs (*Reduviidæ*), but their significance for animals is negligible. The bed-bugs (*Cimicidæ*) are probably more important as blood-suckers than as irritating forms. Numerous species of small *Diptera*—mosquitoes, sandflies, gnats and others—can be extremely irritating to stock. They will be dealt with later. The irritant nature of the bite in these cases is due to the saliva, which is carried by the hypopharynx to the prestomum and is injected into the wound. The saliva contains anticoagulatory and probably also other substances, like hæmolysins and agglutinins, which have been demonstrated in certain cases, and which serve to prevent blocking of the food channel and possibly also to prepare the blood for digestion. A useful summary of the work done on this subject is given by Hecht.* This author has also shown that the mosquito is not poisonous on account of the presence of yeasts in the salivary glands, as suggested by Schaudinn.

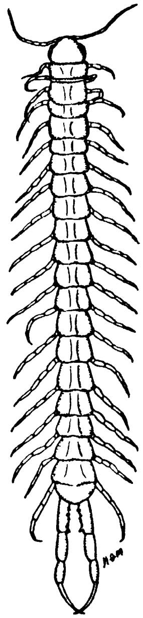

FIG. 195.—A CHILOPOD, DORSAL VIEW. (ORIGINAL.)

The *symptoms* produced by these arthropods vary according to the species of parasite and of host and the individual susceptibility of the host. Pruritus is usually marked. The mildest form of lesion is a vesicle or a small œdematous swelling which soon disappears, leaving a red mark for a time. In other cases a papule may form immediately or after a few hours and then develop into a vesicle, which opens and pours out a fluid which hardens on the skin. The lesion may heal at this stage, or necrosis of the affected tissues takes place, or complications set in on account of secondary infection, which occurs readily when the animal scratches itself. Marked œdematous infiltration of the surrounding tissues occurs in some cases.

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* *Dermatol. Wschr.*, 88 (23): 793-848. 1929.

For the *treatment* of insect bites alkaline substances, such as dilute ammonia or soft alkaline soap, are the most suitable, since the injected material is usually acid and becomes inert if it is neutralised. Ichthyol ointment is also recommended.

(2) The *stinging insects* all belong to the *Hymenoptera*. The sting is usually a modified ovipositor and is then found only in the females. In the bee there is a poison reservoir and the poison glands are of two types, one producing an alkaline and the other an acid secretion. When the bee stings, the tip of the abdomen with the whole poison apparatus breaks off and remains in the wound. The muscles of the organ remain active for a considerable time and force poison out of the reservoir into the tissues, so that it is necessary to remove the sting as soon as possible. It has frequently been shown that bees sting more readily on a dark than on a white surface.

The sting produces local necrosis with infiltration of lymphocytes, hyperæmia and more or less extensive œdema. Some individuals are much more susceptible than others and some human beings have a high susceptibility, so that death may be caused by shock. The stings of a large number of bees may cause death on account of collapse, shock or suffocation, the latter being due to œdema of the head and neck.

For *treatment* alkalies are useless, but hot compresses give relief, and if severe symptoms of collapse or shock develop, strychnine injections may be necessary. In case of threatened suffocation tracheotomy is indicated.

Some species, like bumble-bees, hornets and wasps, sting several times and the sting does not break off so easily. Most ants also possess poison glands and stings, but seldom use them. Some species have no stings, but make a wound by biting and then inject the poison into it. Bees are stated to add a small quantity of poison to their honey as a preservative, and some species of bees make poisonous honey, but in the latter case the poison is probably derived from plants.

(3) *Nettling Forms.*—Many hairy caterpillars produce intense irritation by means of their hairs, which are hollow and bear a poison gland at the base. The hairs break off and remain in the skin of the affected animal or person. The scales of the " brown-tail moth " (*Porthesia chrysorrhœa*) and of some other moths may cause dermatitis and bronchitis, and the caterpillars of *Porthesia* are also stated to cast off hairs which are very irritating.

Poisonous caterpillars are known to cause stomatitis and even enteritis in animals if they are frequent in a pasture. In cases of dermatitis the application of ammonia, followed by 10 per cent. ichthyol ointment, is recommended.

(4) *Cryptotoxic Forms.*—The well-known Spanish fly or blister beetles (*Meloidæ*) possess very irritating body fluids, containing cantharidin as the active principle. Powdered beetles or extracts have long been used for blistering and formerly also as aphrodisiacs. The action in the latter case is due to irritation and the kidneys suffer severely. Cases of poisoning of cattle from ingesting these beetles with their food are known, and the flesh of such animals is believed to be poisonous for human beings. In treating such cases oils should be avoided, as they tend to increase absorption of the poison. Saline purgatives are indicated.

Of other cryptotoxic insects the most important are the caterpillars of the cabbage butterfly (*Pieris brassicæ*), which cause stomatitis, colic, and paralysis of the hind-legs in animals.

Arachnida.—In *scorpions* the last abdominal segment forms the sting, which contains a pair of well-developed poison glands and ends in a hollow spine. The smaller species may cause painful stings, but these are not fatal. The larger tropical and subtropical species are frequently very poisonous. The poison causes elevation of blood pressure and consequently increased glandular activity, especially lachrymation, salivation and a nasal discharge. There are also muscular spasms, and death is due to asphyxia.

Treatment consists in the application of a ligature proximal to the wound—not to be maintained for longer than half an hour—and the injection of a 1 per cent. permanganate solution, as in the case of a snake bite. The stings of slightly poisonous forms can be treated by the local injection of cocaine and adrenaline, which alleviates pain. For very poisonous forms antivenoms are prepared by hyperimmunisation of animals, and such a serum, prepared from one species, protects against closely related forms, but not against others. The scorpions themselves appear to contain antitoxins, so that they can resist the stings of other scorpions.

The *Solpugida* have very powerful chelicerae and can inflict severe wounds, but they have no poison glands. Their bites may become secondarily infected, especially from the mouth parts of the solpugids themselves, which are carnivorous, and therefore require only antiseptic treatment.

The *Araneida*, or spiders, have poison glands which lie in the cephalothorax and open through pores on the tips of the chelicerae. The poison is used to kill small animals, especially insects, for food, and most spiders are not able to bite through the skin of larger animals and man, nor are they sufficiently poisonous to do much harm. There are, however, a few species that are well known to be very dangerous.

The name "tarantula" is derived from a spider of the family *Lycosidæ*, *Lycosa tarantula*, which was believed to be the cause of an hysterical condition, and it was greatly feared in the Middle Ages. This spider is not poisonous to man or domestic animals. The name "tarantula" is now usually applied to many large spiders of the *Avicularoidea*, which may inflict severe bites, but are not fatally poisonous. The wounds they make may become infected with bacteria from their mouth parts.

The most poisonous spiders are species of the genus *Latrodectus*, which occur in many tropical and subtropical countries, and are called "hour-glass spiders," on account of a red hour-glass-shaped spot which is frequently present on the ventral side of the abdomen. *L. mactans*, the "black widow," is one of the best-known species. The female measures up to 3 cm. in length, including the legs. The body is glossy black; on the dorsal side of the abdomen the males and young females have several lighter, spotted stripes which are transversely arranged and run down the sides. On the ventral surface there are brick-red spots which may form the shape of an hour-glass or of a cross. The legs are long and tapering. In the lighter-coloured species the joints of the legs are usually dark. The spiders live in buildings or in shrubs and spin a coarse web, and their eggs are laid in spherical masses with an irregular surface. These spiders are very poisonous and frequently also aggressive.

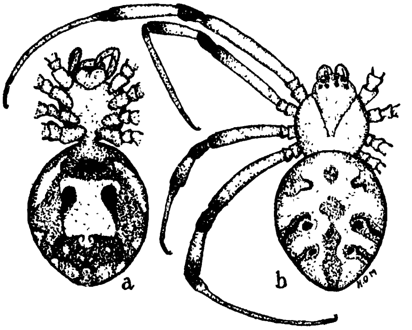

FIG. 196.—*Latrodectus*, A SOUTH AFRICAN SPECIES, SHOWING CHARACTERISTIC SHAPE AND ORNAMENTATION. (ORIGINAL.)

a, Ventral; *b*, dorsal view. (× about 1½ natural size.)

The symptoms, as described by various authors,* are general rather than local, although severe local pain may occur. A general convulsive trembling of medullary origin is stated to be characteristic in guinea-pigs. In man shooting pains in the hips and marked abdominal pains are common, and are followed by numbness and paresis of the lower limbs. Dizziness and a general feeling of oppression occur. The blood pressure is elevated, hence there is marked salivation and cold perspiration, later followed by thirst and sometimes retention of urine.

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* Hall and Vogelsang, *U.S. Naval Med. Bull.*, 30 (4): 471-478, 1932; de Asis, *Med. Journ. Australia*, 2 (11): 345-346, 1932; Troise, *C. R. Soc. Biol.*, 102 (36): 1097-1098, 1929; and others.

The respiratory system is affected, resulting in dyspnœa and cyanosis. Sometimes vomiting and constipation are seen. The course may be from a few hours to about 3 days. In cases that die soon, pulmonary œdema is the prominent lesion; in later cases necrotic foci are seen in the liver, kidneys, spleen and adrenals. Recovery is not infrequent.

Treatment in general as for snake-bite. Potassium permanganate is stated to destroy the poison rapidly. Warm baths give relief. Antivenoms are made and used with success, but must be injected very soon after the bite has occurred.

Chiracanthrium nutrix is a European spider which may cause symptoms of poisoning, and some of the *Epeiridæ*, or orb-weavers, contain poisonous substances in their body fluids and eggs which may give rise to symptoms in animals that swallow them accidentally.

The *Acarida* frequently secrete irritating and other harmful substances, which may in some cases be saliva, but in other cases are probably definite toxins, as, for instance, the tick paralysis caused especially by *Ixodes* species and *Dermacentor andersoni.* Many acarids transmit infectious diseases.

Ticks, especially those with long mouth parts, often produce severe wounds, damaging hides and causing loss of teats in cows. They should never be forcibly pulled off, as the capitulum is liable to become detached and remain in the skin.

Although most authors are of the opinion that mites which may be present in foodstuffs are not harmful to animals, Höve and Fiedler* report several cases of sudden death in horses and pigs which showed at autopsy a slight enteritis, and the presence of the meal-mite *Aleurobius farinæ*, in scrapings of the intestinal mucosa. No other explanation for the deaths of the animals could be found. The mites were also present in the grain supply from which the animals had been fed. Karmann† also mentions *A. farinæ* and the hay-mite *Glyciphagus domesticus* as being harmful to domestic animals when present in foodstuffs.

B. ARTHROPODA AS PARASITES AND TRANSMITTERS OF DISEASE

CLASS INSECTA

Order ORTHOPTERA

Cockroaches.—The commonest cockroach in most countries is the "croton bug," *Blatella* (*Ectobia*) *germanica.* The adults measure about 15 mm. in length to the tips of the wings, which are present in both sexes. Their colour is light brown, with two longitudinal dark stripes over the prothorax and wings. Fairly common is also the Oriental roach, *Blatta orientalis*, which is almost black, about 25 mm. long, with wings that do not quite reach the tip of the abdomen in the male and are vestigial in the female.

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* *Tierärtzl. Rdsch.*, 38 (34): 584-585. 1932.

† *Ztschr. f. Infekt. kr. par. Kr. u. Hyg. d. Haust.*, 41 (1/2): 116-132. 1932.

Cockroaches live preferably in warm places and roam about in the dark. They feed on starchy or sugary materials, but will eat almost anything if necessary, and are found most frequently in kitchens, bakeries and storerooms in which cereal products are kept. They are not parasites, but may easily spread disease on account of their habits. They have been proved to carry various fungi and protozoa and to act as intermediate hosts for several species of parasitic nematodes.

The eggs are laid in egg-cases which each contain a number of eggs, and which may be seen protruding from the abdomen of the females, since they are carried about for some time. The egg-cases are deposited in crevices and the rate of development of the eggs and the young cockroaches depends very much on the temperature and the available food supply.

Control of these insects is difficult because they breed rapidly and new infections are readily introduced. Traps are often used, and they may assist to reduce the number of the insects, but are not much good for complete extermination. Poisons are more effective, but cockroaches are wary insects, and the croton bug especially does not easily take poison. Pure sodium fluoride kills the insects, and is not very poisonous for higher animals. Mixed with equal parts of flour or finely ground sugar it is also useful. Borax mixed with three parts of powdered chocolate is quite effective. The best method of extermination, if applicable, is cyanide fumigation. Other fumigants, like sulphur dioxide and carbon bisulphide applied in the ordinary way, are not effective. D.D.T. kills some species.

Order COLEOPTERA

The beetles are important as carriers of disease-producing organisms. Scavenger beetles that feed on carcasses have been shown to carry anthrax bacilli, and other pathogenic bacteria may also be spread in this way. Dung beetles may possibly spread bacteria occurring in fæces, but they are especially important as intermediate hosts of numerous tapeworms and nematodes.

Order DIPTERA

Sub-Order ORTHORRHAPHA

The larvæ are eucephalous or hemicephalous; the pupæ are obtectate, rarely coarctate; the adult emerges through a T-shaped slit on the dorsal aspect of the puparium. Ptilinum absent.

Family CHIRONOMIDÆ

These small diptera are commonly known as "gnats" or "midges." The thorax is strongly arched. The proboscis is short and the antennæ are long, consisting of 13-15 segments which are pilose in the female and plumose in the male. The wings are hairy, but bear no scales; they usually have dark spots.

The larvæ are known as "blood-worms" and develop in moist places like mud or sand at the edges of streams or pools, in tree holes or in moist rubbish heaps.

The commonest genera are *Culicoides* and *Ceratopogon*. These are small insects, about 1-3 mm. long, and can pass through ordinary mosquito screens. The females of some species attack man and animals to suck blood, and can cause great annoyance if they occur in large numbers. Their bites cause itching and swelling. *Culicoides austeni* is the intermediate host of the human filariid *Dipetalonema perstans*. *C. nubeculosus* transmits *Onchocerca cervicalis*, while *C. pungens* is believed to transmit *O. gibsoni* in Malaya. According to Du Toit* species of *Culicoides* transmit blue-tongue of sheep and probably also horse-sickness.

Family SIMULIIDÆ

These are dark-coloured, relatively small, thick-set flies, commonly known as "black flies" or "buffalo gnats." The thorax is high and the legs are short. The antennæ are also short and consist of 11 segments.

The eggs are laid on stones or plants just below the surface of the water in running streams. The female inserts her ovipositor into the water to lay, and deposits several hundred eggs at a time. They hatch in 4-12 days, depending on the temperature. The larvæ are cylindrical and attach themselves by means of a posterior sucker-like organ which is armed with small hooks, but they are able to move about. Anteriorly are the mouth parts and a pair of brush-like organs; the larvæ are carnivorous. Near the anterior extremity the ventral surface bears an arm-like appendage which has a circlet of hooks at its free end and which the larva uses when it moves about. The larvæ moult six times; at the last moult the pupa appears. The mature larva spins a triangular cocoon on the surface to which it is attached, and in this the pupal stage is passed.

The simuliids occur in practically all parts of the world, but are troublesome especially in warm countries. They cause great annoyance and irritation. Swarms of these flies will keep cattle from grazing or cause them to stampede and hurt themselves. They bite on the legs and abdomen, or on the head and ears. The bites give rise to vesicles which burst, or wart-like papules, which may be very troublesome on the teats of cows and take weeks to heal. Poultry are often attacked and may even become anæmic from loss of blood. The flies are active in the morning and evening, resting during the hot part of the day on the under-side of leaves near the ground. Certain species of *Simulium* transmit Onchocercas (filarial worms) and *S. venustum* transmits *Leucocytozoon anatis*, a blood parasite of ducks, while *L. smithi* of turkeys and *L. caulleryi* of fowls are also transmitted by these insects. *S. ornatum* transmits *Onchocerca gutturosa* of cattle.

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* *Ond. Journ. Vet. Sc. Anim. Ind.*, 19 (1-2): 7-16. 1944.

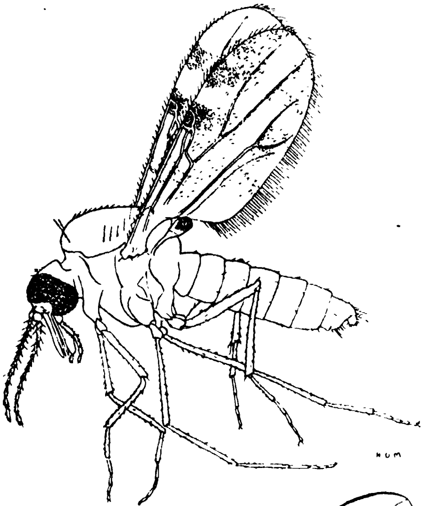

FIG. 197.—*Culicoides*. (ORIGINAL.)

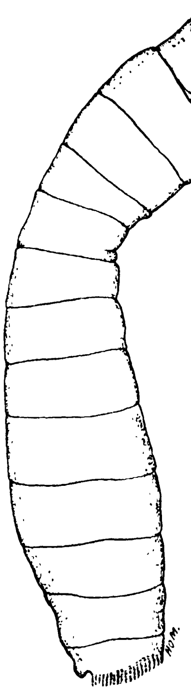

FIG. 199.—*Simulium* LARVA. (ORIGINAL.)

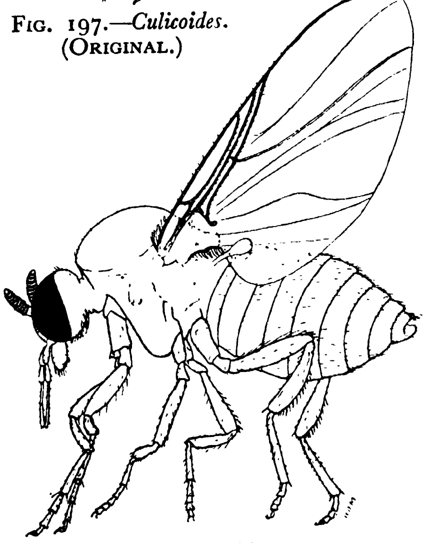

FIG. 198.—*Simulium*. (ORIGINAL.)

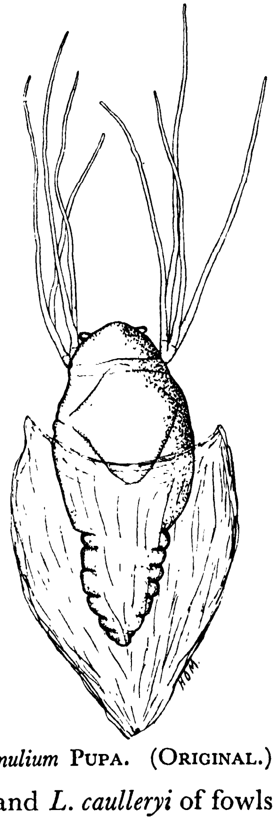

FIG. 200.—*Simulium* PUPA. (ORIGINAL.)

Control is difficult because the adults fly far, sometimes 6 kilometres or more. The larvæ cannot be killed in streams by chemicals without killing off most other animal life in the water. Open poultry houses can be protected by fine screen wire.

Family PSYCHODIDÆ

The *Psychodidæ*, commonly known as "sand-flies" or "owl midges," are small, moth-like flies, rarely over 5 mm. long. Their bodies and wings are hairy. The legs are long, rarely short. The wings are held roof-like over the abdomen during rest. The mouth parts are short or of medium length. The antennæ are long, consisting of 16 segments which often have a beaded appearance, and they are thickly covered with hairs. The palpi are recurved and hairy.

The eggs are laid in moist, dark places, as in rock crevices and between stones. The female of *Phlebotomus papatasii* lays about forty to eighty eggs at a time. A temperature of over 15° C. is required, else the embryo becomes dormant. Under favourable conditions the whole life-cycle can be completed in about 6 weeks. The larvæ resemble small caterpillars and feed mainly on fæces of larger animals.

The flies are active at night only and hide during the day in dark corners. They are weak fliers and the females of some species are blood-suckers. They can pass through ordinary nets, or will otherwise search for an opening to get through. *P. papatasii* is the vector of human papatasi fever and species of *Phlebotomus* are probably also the vectors of *Leishmania donovani*, the cause of kala-azar.

Since relatively little is yet known about the biology of these flies, control measures cannot be suggested. Fine screens are required to keep the insects out, and they must be in good order.

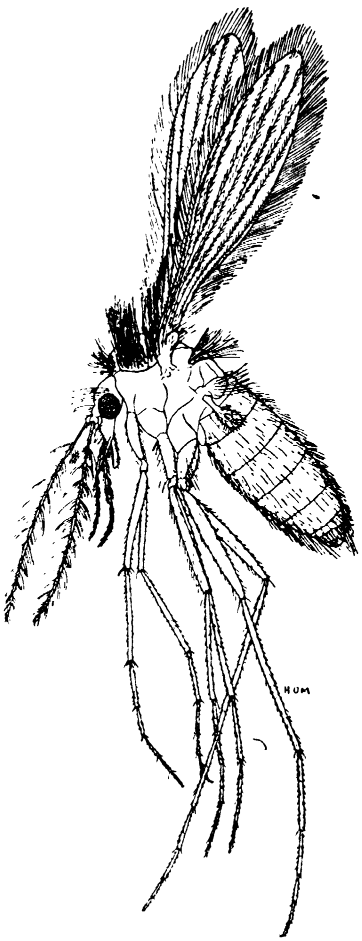

FIG. 201.—*Phlebotomus* SP. (ORIGINAL.)

Family CULICIDÆ

The mosquitoes are slender *Nematocera* with small, spherical heads and long legs. The antennæ of 14-15 segments are conspicuous and are plumose in the males. The proboscis is long and slender. The abdomen is elongate and the thorax is characteristically wedge-shaped, with the broad end dorsally. The wings are long, narrow and folded flat over

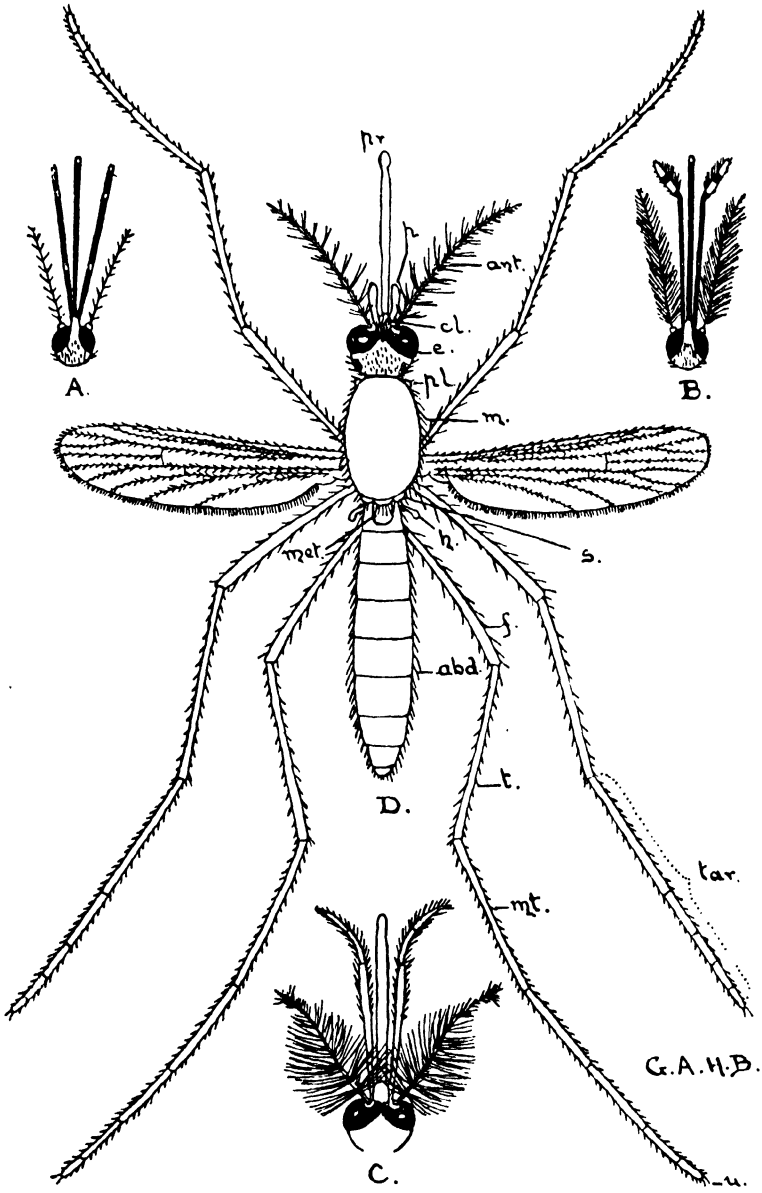

FIG. 202.—EXTERNAL ANATOMY OF MOSQUITOES. (AFTER BEDFORD.)

A, Head of *Anopheles* sp., female; B, head of *Anopheles* sp., male; C, head of *Culex* sp., male; D, *Culex* sp., female; *abd.*, abdomen; *ant.*, antenna; *cl.*, clypeus; *e.*, eye; *f.*, femur; *h.*, halter; *m.*, mesothorax; *met.*, metathorax or post-scutellum; *mt.*, metatarsus; *p.*, palp; *pl.*, prothoracic lobe; *pr.*, proboscis; *s.*, scutellum; *t.*, tibia; *tar.*, tarsus; *u.*, ungues, or claws.

the abdomen during rest. They bear elongate, leaf-like scales along the margins and on the veins.

The eggs are laid on water or on floating vegetable matter, and each species has its special requirements, which are usually very restricted. Some species lay their eggs only in fresh rain water, others in stagnant pools or in any vessel that contains water; others lay in quiet pools at the edges of streams and some even lay in salt water. The temperature of the water, the nature of the microflora in it, the presence or absence of decayed matter and the acidity or alkalinity are all deciding factors. The eggs may be deposited in masses or " egg-rafts " as in the case of *Culex*, or singly as in the case of *Anopheles* and *Aedes*. In the egg-rafts the eggs are arranged vertically with their anterior ends towards the water. The anopheline egg is boat-shaped and is provided with a float on either side and a frilled edge.

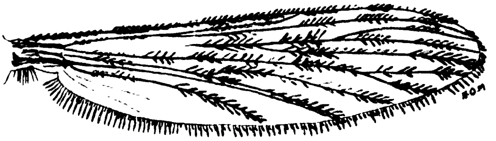
FIG. 203.—WING OF A MOSQUITO. (ORIGINAL.)

The larvæ are eucephalous and have a distinct thorax and abdomen. The head bears eyes, antennæ and several hairs. The mouth parts are masticatory, and are surrounded by brushes that produce currents in order to bring food particles to the mouth. The unsegmented thorax bears feathered hairs and the abdomen, which is segmented and also hairy, is provided in the anophelines with certain palmate hairs, by means of which the larva is able to cling to the surface of the water. The stigmata from which tracheæ pass through the whole body are situated on the fused eighth and ninth abdominal segments. The tenth segment bears feathered hairs and tracheal gills, which are especially well developed in forms like *Aedes*, that feed at the bottom of the water. All mosquito larvæ, except those of *Anopheles*, are provided with a siphon or tube which arises from the dorsal aspect of the eighth and ninth abdominal segments and surrounds the stigmata. It is closed at its apex by chitinous valves that open when the larva goes to the surface of the water to breathe. The larvæ then hang down into the water at an angle, while anopheline larvæ lie against the surface. The larvæ moult four times, the last time at the moment of pupation.

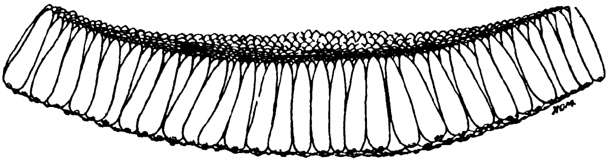
FIG. 204.—*Culex* EGG RAFT. (ORIGINAL.)

The pupa has a rounded " body," which consists of head and thorax, and an elongate abdomen, flattened dorso-ventrally and flexed underneath the body. Through the delicate cuticle of the latter the wings and appendages of the adult can be seen. From the dorsal aspect of the thorax, and attached to the lateral stigmata, there arise a pair of tubes or respiratory trumpets, through which the pupa breathes at the surface of the water. The pupæ are not quite as active as the larvæ.

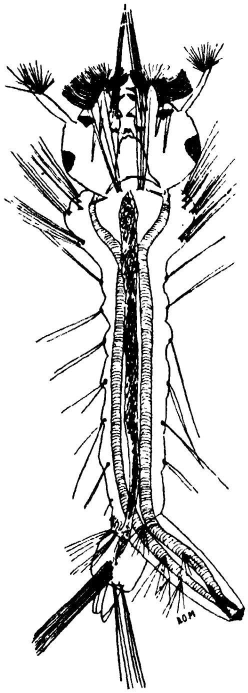

FIG. 205.—CULICININE LARVA. (ORIGINAL.)

The time required for development differs according to the species and varies from about 7-16 days under favourable circumstances, which means especially a sufficiently high temperature. Cold weather may prolong the larval period to several months. The eggs of some species can also resist cold or drying for a considerable time. There are great variations in the seasonal prevalence of different species, mainly due to temperature requirements; most species breed in warm weather, but in warm climates some breed only in winter. Females which find it too late to lay may hide away and hibernate, or æstivate in hot climates, until the next season. The hiding-places are usually relatively dark surroundings with an even temperature, like cellars, barns and lofts under thatched roofs.

Apart from the presence of permanent water, rainfall has a marked influence on the number of mosquitoes for several reasons. If there is little or no rain, mosquitoes will be scarce because their numbers are limited by their natural enemies in the permanent breeding-places. After a rain the numbers will increase, since the mosquitoes develop rapidly and are not restricted by enemies in the new breeding-places. Much rain, on the other hand, washes away the larvæ and usually decreases the number of mosquitoes, unless pools remain afterwards. The young stages can be transferred to a new area by water which flows intermittently.

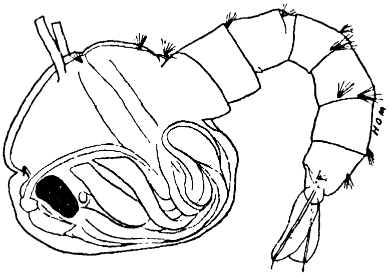

FIG. 206.—CULICININE PUPA. (ORIGINAL.)

The adults may fly fair distances, especially anophelines, which, according to recent investigations, can travel several kilometres from their breeding-ground to feed and return in the morning. They may be carried much further by winds or cover long distances in successive stages. They can also be transported in all kinds of vehicles. Some species readily enter buildings, while others do not.

Mosquitoes can be fed on fruit juices and sugar water, and the males exist normally on such food, but the females are blood-suckers and appear to require a meal of blood in order to lay eggs. The females seem to be attracted by the warmth radiating from the skin of their host. They are active at night and are attracted by light, while during the day they hide in dark corners.

Although mosquitoes can be a great nuisance and cause painful bites, their chief importance lies in the fact that they are the intermediate hosts and vectors of several very important parasitic and ultravisible virus diseases of man and domestic animals. In the case of the domestic animals mosquitoes transmit several filarias, and possibly fowl-pox and blue-tongue. *Aedes* species and *Culex quinquefasciatus* transmit *Plasmodium gallinaceum* Brumpt, 1935. *Culex* species transmit *Spirochæta anserina. Mansonia* species transmit rift valley fever. *Aedes dorsalis* and *A. nigromaculis* have been incriminated as transmitters of equine encephalomyelitis in the United States.

Control.—The young forms can be destroyed by various poisons like D.D.T., phenothiazine, paris green, or by covering the water with paraffin, which enters the stigmata of the insects and kills them. Of great importance are also drainage, in order to clear up the breeding-places, and biological methods of control by natural enemies, such as the small fish *Gambusia holbrooki,* which occurs in certain North American lakes and devours large numbers of mosquito larvæ and pupæ.

The adult mosquitoes are less easily controlled. They can be kept out by good nets and wire screens. They can also be killed off in buildings by spraying with D.D.T. and extracts of pyrethrum, of which several preparations are on the market. The adults should especially be killed off in winter, particularly in cold countries, where they are the main hibernating forms and where they are found in cellars and other warm, sheltered parts of buildings. Citronella oil is used to repel the insects from human beings, and animals can be protected by smearing them over lightly with paraffin, but it should be remembered that the latter acts as a depilatory on horses.

Family TABANIDÆ

These insects, commonly known as " horse-flies " or " blind flies," are large, robust flies with powerful wings and large eyes. The latter are almost contiguous (holoptic) in the males and separated by a narrow space in the females, and project posteriorly beyond the lateral margins of the thorax. The antennæ have two short basal segments and a third which is large and usually ringed. The wing venation is very characteristic, especially the branching of the fourth longitudinal vein (Fig. 190). The proboscis is relatively short in *Tabanus* and *Hæmatopota*, longer in *Chrysops* and very long in *Pangonia*. These are the most important genera. Species of *Tabanus* are frequently brown with longitudinal stripes on the abdomen, and hold their wings horizontal when at rest. *Hæmatopota* has greyish wings which are slightly arched, while *Chrysops* has spotted wings, standing divergent when at rest, and eyes of a metallic colour. *Pangonia* also holds its wings divergent and can easily be recognised by the elongate proboscis, which projects forward.

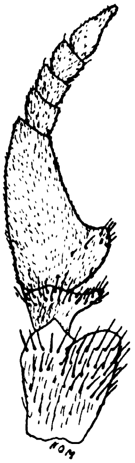

FIG. 207.—*Tabanus*, ANTENNA. (ORIGINAL.)

Life-Cycle.—The eggs are laid in the vicinity of water, usually on the leaves of plants. The larger species lay 500-600 eggs, the smaller 300. The eggs are about 2 mm. long and light in colour, but turn dark after a while. The larvæ hatch after 4-7 days and drop into the water, or on mud, into which they disappear. They are maggot-like and the body has 11 segments, besides the cephalic portion which is not conspicuous. Each segment has eight fleshy tubercles. The mouth parts are prehensile and masticatory, since the larvæ are carnivorous. There are three-jointed antennæ and the large lateral tracheæ open on the penultimate segment, which also bears a retractile siphon tube. The larvæ feed on small crustacea or even on one another, and grow for 2-3 months, performing several ecdyses. Finally they pass through a quiescent stage and then pupate. The pupa is brown and subcylindrical; the abdominal segments are movable, and in the anterior part the appendages of the imago can be distinguished. This stage lasts about 10-14 days. The whole life-cycle takes 4-5 months under favourable conditions, but low temperatures prolong development and the larvæ may hibernate. The eggs are parasitised by certain small *Hymenoptera*.

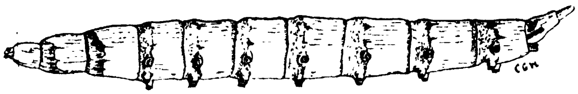

FIG. 210.—*Tabanus* LARVA. (× 4.) (ORIGINAL.)

Biology of Adults.—The flies are seen in summer and are very fond of sunlight. They abound especially near their breeding-places and are most active on hot, sultry days. They attack chiefly large animals like horses and cattle. Some feed mainly on the under-side of the

PLATE X

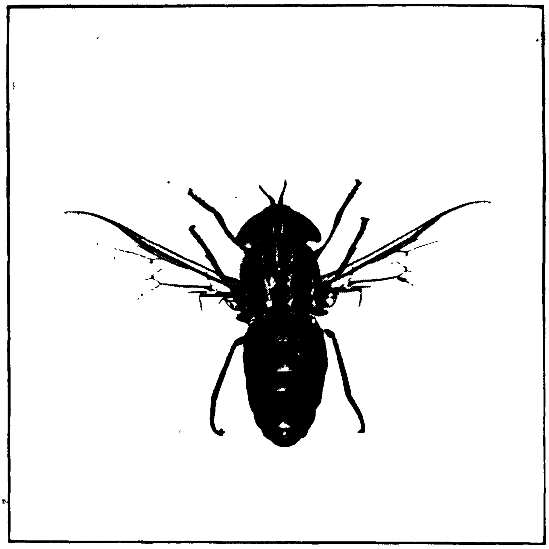

FIG. 208.—*Tabanus tæniola*, MALE.

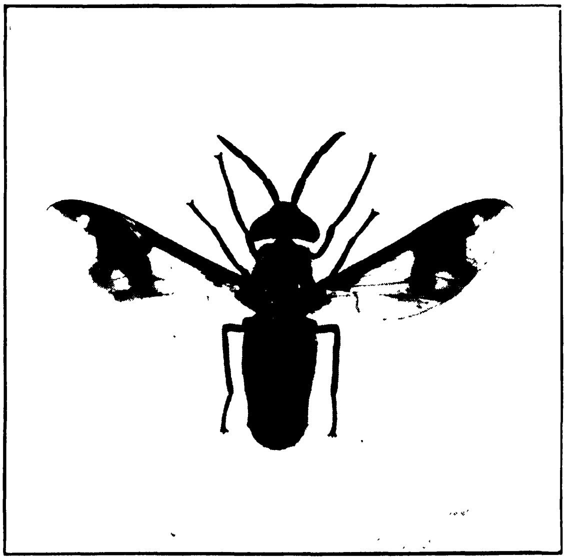

FIG. 209.—*Chrysops stigmaticalis.*

[*To face page* 306.

abdomen around the navel or on the legs; others also bite on the neck and withers. They bite a number of times in different places before they are replete, and from the wounds made by them small quantities of blood usually continue to escape and are sucked up by non-biting *Muscidæ*. The flies feed about every 3 days. After feeding they rest on the under-side of leaves, or on stones or trees, for a few hours.

The bites of the *Tabanidæ* are painful and irritating and may give rise to weals in soft-skinned animals. Horses and cattle are restless when troubled by these flies and may become unmanageable if they are in harness. The flies, as well as the *Muscidæ* that come after them, may act as mechanical transmitters of bacterial diseases like anthrax and the virus of equine infectious anæmia. Several species of *Tabanus*, and more rarely *Hæmatopota* and *Chrysops*, are the vectors of *Trypanosoma evansi*, the cause of surra in domestic animals. The non-pathogenic *Trypanosoma theileri* is transmitted by *Tabanus* and *Hæmatopota.*

Control is difficult. Where drainage is possible the breeding-places may be destroyed by this method. The flies have a habit of skimming over water and occasionally dipping their bodies into it; this has led Porchinsky to pour paraffin on the water and he has obtained favourable results. In order to protect animals they should be kept away from places where the flies abound during the hot part of the day. Nets which can be fixed to the harness of horses are obtainable in some countries. A contraption in the form of a dark passage in which the flies are scraped off the animals by palm leaves and then automatically collected in traps in the roof has been described. This method may be useful to clean the animals for any special purpose, but could hardly be effective in reducing the number of flies.

Sub-Order CYCLORRHAPHA

The larvæ are acephalous; the pupæ are coarctate; the adult usually has a ptilinum (except in the *Aschiza*), and emerges through a circular orifice at the anterior end of the puparium. The forms of interest to veterinary parasitology all belong to the *Schizophora*, which have a frontal suture.

Family SARCOPHAGIDÆ

The " flesh flies " are medium-sized to large and thick-set, of a light or dark grey colour. The arista is plumose to about its middle and bare in the distal portion.

These flies lay their larvæ or eggs in decaying animal or vegetable matter, especially in meat and sometimes in wounds. Species of *Sarcophaga* are viviparous and can drop their larvæ from a fair height on to meat through the meshes of gauze-wire covers. The sarcophagid flies are not very important in connection with myiasis (parasitism by dipterous larvæ), although species of *Wohlfahrtia* may sometimes cause this condition. *W. vigil* deposits its larvæ on the intact skin of children, rabbits and guinea-pigs. The larvæ penetrate through the skin and live there for 4-12 days, producing inflamed and indurated foci, 6-12 mm. in diameter, with a central opening through which the posterior extremities of the larvæ protrude. *W. euvittata* deposits its larvæ in the egg packets of locusts, or sometimes in the soft young insects.

Family ŒSTRIDÆ

The adults are hairy flies which have rudimentary mouth parts and do not feed. They usually lay their eggs on animals. The larvæ are parasitic maggots and consist of 12 segments, of which the first two are fused together. Oral hooks are usually present, but there is no head. The posterior stigmata open through semicircular plates which may be retractile. The larvæ moult twice during their parasitic life and leave the host when they are full grown to pupate in the ground. They feed on the body fluids of the host or on exudates which surround them.

Genus **Gastrophilus** Leach, 1817

The larvæ of several species of this genus are parasites of equines and are known as "bots." They are rarely found in dogs, pigs, birds and man. The adult flies are brown in colour and hairy, somewhat resembling bees, but have, of course, only one pair of wings. *G. intestinalis* (de Geer, 1776) (syn. *G. equi*) is the commonest species. The adults of this species are about 18 mm. long and a dark, irregular, transverse band runs across either wing. The third-stage larvæ of the different species can be differentiated as follows:

1. Without spines . . . . *G. inermis* (Brauer, 1858)
   One row of spines on each segment . *G. veterinus* (Clark, 1797)
   (syn. *G. nasalis* Linné, 1761)
   Two rows of spines on each segment 2
2. Dorsal surface with complete rows of spines only on segments 2-5
   G. pecorum (Fabricius, 1794)
   Dorsal surface with complete rows of spines only on segments 2-8. 3
3. Spines of first row larger than spines on second row . . . .
   G. intestinalis (de Geer, 1776)
   Spines of first row smaller than spines on second row . . . .
   G. hæmorrhoidalis (Linné, 1761)

PLATE XI

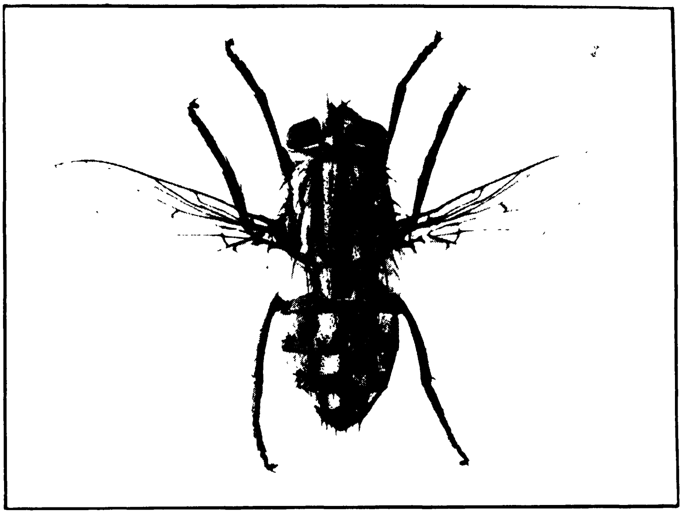

Fig. 211.—*Sarcophaga hæmorrhoidalis*, Female. (Original.)

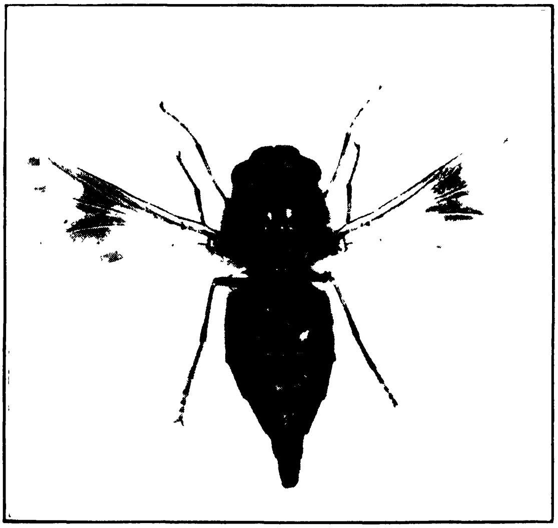

Fig. 212.—*Gastrophilus intestinalis*, Female.

[*To face page* 308.

Biology.—The adult flies occur during the latter half of the summer and live only a few days, rarely up to 3 weeks. According to Dinulescu* *G. pecorum* lays its eggs on the hoofs of equines and on inanimate objects near the animals, also on their food. The other species deposit their eggs on the hairs of the host. The female fly hovers about the animal with its ovipositor extended, and repeatedly darts at it to glue an egg to a hair. A large number of eggs may be laid in succession. *G. intestinalis* deposits its eggs mainly around the fetlocks of the forelegs, also higher up the legs and in the scapular region. *G. veterinus* lays on the hairs of the intermandibular region, while *G. hæmorrhoidalis* and *G. inermis* deposit their eggs on the hairs around the mouth and on the cheeks. The eggs of *G. pecorum* and *G. hæmorrhoidalis* are dark in colour, those of the other species pale yellow; they are elongate, pointed at the attached end and operculate at the other.

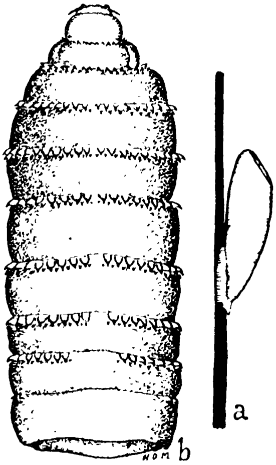

FIG. 213. — *Gastrophilus intestinalis* : *a*, EGG ON HAIR; *b*, LARVA, DORSAL VIEW. (ORIGINAL.)

The eggs are ready to hatch in 10 days or more (5-6, according to Dinulescu). The eggs laid near the mouth of the horse hatch spontaneously, while those of *G. intestinalis* and *G. pecorum* require to be licked or rubbed by the animal. The investigations of several authors (Hobmaier, Dinulescu, Rubaud, Hawden and Cameron) have shown that the larvæ are not swallowed directly into the stomach, but that they penetrate into the mucosa of the mouth, and gradually wander down in this way at least as far as the pharynx. The larvæ of *G. intestinalis* and *G. hæmorrhoidalis* are found chiefly in the mucosa of the tongue, those of *G. pecorum* and *G. inermis* in the mucosa of the cheeks. The larvæ of the latter species, perhaps also those of *G. hæmorrhoidalis*, even pierce the skin of the face and wander in it to the mouth, leaving conspicuous tracks behind them. In human beings such cases of " creeping myiasis " due to *Gastrophilus* larvæ are also known. Apparently as a result of these migratory habits the larvæ may occasionally go astray, and they have been found in various thoracic and abdominal organs, the sinuses of the head and even in the brain. The larvæ of *G. intestinalis*, after wandering in the tongue for 21-28 days, become attached in the cardiac portion of the stomach, rarely in the fundus or the pylorus; they have a reddish colour. Those of *G. veterinus* are pale yellow and attach themselves in the pylorus and the duodenum. The larvæ of *G. pecorum* are blood-red in colour; the second and sometimes also the third stage is found in the pharynx and the upper part of the œsophagus, but the third stage is usually attached in the fundus of the stomach. The young stages of *G. hæmorrhoidalis*, which are red, are occasionally found in the pharynx, but later they settle in the stomach.

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* *Ann. d. Sci. Nat.*, [10] 15; *Zool.*, (1): 1-183. 1932.

The larvæ remain in the host for 10-12 months and then pass out through the intestine. Those of *G. pecorum* and *G. hæmorrhoidalis* again attach themselves for a few days in the rectum, where the latter species acquires a greenish colour. Some larvæ may leave the host in the late autumn, but usually they pass out in the spring. They pupate in the ground for 3-5 weeks and then the flies emerge.

Pathogenesis, Lesions and Symptoms.—The flies which lay their eggs on the head of the host annoy the animals and may even cause them to become panicky and run away. The migrating larvæ are found in the superficial layers of the buccal epithelium and produce no reaction. When later they attach themselves in the pharynx, stomach or duodenum, an inflammatory process produces a ring-like thickening around the larva. It is suspected that the presence of larvæ in the pharynx may lead to crib-biting. Very rarely perforations of the pharynx, œsophagus or stomach have been seen. Clusters of larvæ around the pylorus interfere with the action of the sphincter and the passage of food. The larvæ that pass through the intestine, and especially those that attach themselves anew in the rectum, cause an irritation by means of their spines. The most serious effect of these parasites is, however, due to toxic excretions, to which the animal becomes hypersensitive and which produce general debility. While the danger of " bots " is usually much overrated by laymen, veterinarians have often attached too little significance to these parasites, except in some countries like the United States, where concerted efforts have been made to exterminate the parasites in large areas.

Diagnosis.—The eggs can be found by examining the sites in which they are deposited, and larvæ in the pharynx can be seen at direct inspection, but there is no way of diagnosing the presence of the parasites in the stomach.

Treatment.—The most effective remedy is carbon bisulphide, administered as for *Habronema* (p. 236) or in capsule. Carbon tetrachloride, as given for strongyles (p. 170), is also fairly effective. Only the larvæ in the stomach are killed by these methods. The animals should be treated in the autumn after the flies have disappeared, and at the same time any eggs present on the body should also be removed.

Prophylaxis.—Frequent grooming removes some eggs and the larvæ of *G. intestinalis*, which hatch as a result of the friction. Singeing and clipping may be useful, but more advisable is the weekly application of a 2 per cent. carbolic dip to those parts of the animal on which the eggs are deposited, in order to destroy them.

Genus **Œstrus** Linné, 1761

Œstrus ovis Linné, 1761, the "sheep nasal fly," has a dark grey colour with small black spots which are especially prominent on the thorax, and it is covered with light brown hair. The flies hide in warm corners or crevices, and in the early morning they can be seen sitting against walls or other objects in the sun. They occur from spring to autumn, particularly in summer, but in warm climates they are active even in winter. The larvæ live as parasites in the nasal cavity and the adjoining sinuses in sheep and rarely in goats, and have also been found in the blesbuck (*Damaliscus albifrons*). *Œstrus* sometimes also deposits its larvæ in the eyes, nostrils and on the lips of man, where they may develop, causing serious trouble.

The flies deposit their young larvæ around the nostrils of the host, whence they crawl upwards. Sometimes they enter into cavities which have small openings, like those of the turbinated bones or a branch of the frontal sinus, with the result that they are not able to get out when they have grown adult and so they die there. The larvæ develop in the host in about a month or considerably longer. According to Cobbett and Mitchell the larvæ pass the first instar in the nasal passages and remain there for 2 weeks, or up to 9 months during the cold part of the year. The second instar passes into the frontal sinuses and may develop rapidly, leaving the sheep 25 days after infection or considerably longer. The full-grown larvæ crawl out and pupate in the ground for 3-6 weeks, or longer during the cold season, before the fly emerges.

The young larvæ are white or slightly yellow; when they become mature, dark transverse bands develop on the dorsal aspects of the segments. The full-grown larva is about 3 cm. long, tapering anteriorly, and ending with a flat surface posteriorly. There are large, black, oral hooks, connected to an internal "cephalopharyngeal skeleton." The ventral surface bears rows of small spines and the black stigmal plates are conspicuous on the posterior surface.

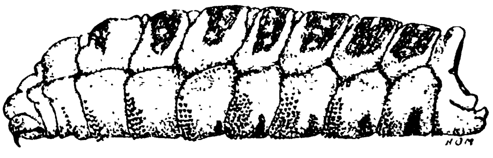

FIG. 215.—*Œstrus ovis*, LARVA, LATERAL VIEW. (× 2.) (ORIGINAL.)

Pathogenesis and Symptoms.—The flies cause great annoyance when they attack the sheep to deposit larvæ, so that the animals stop feeding and become restless. They shake their heads or press their noses against the ground or in between other sheep. When the flies are plentiful, they may thus cause considerable interference with the feeding of the animals. The larvæ irritate the mucosa with their oral hooks and spines, causing the secretion of a viscid mucous exudate, on which they apparently feed. Infected sheep have a nasal discharge and sneeze frequently. They appear to be conscious of the irritation caused by the larvæ; they grate their teeth and lose their appetite, so that emaciation commonly occurs and death is not unusual in severe cases. It is possible that the parasites may also have a toxic influence. According to Mitchell and Cobbett inflammation of the mucosa is always associated with dead larvæ and probably secondary bacterial invasion is the cause of death.

Diagnosis can only be made tentatively from the symptoms, excluding other possible causes like lungworms and chronic bronchial or pulmonary diseases.

Treatment is difficult, since the larvæ are very resistant to the effects of drugs and they cannot easily be reached. Injections through the nostrils are not very satisfactory in heavy infections, since the openings into the sinuses are usually blocked with mucus. An injection directly into the frontal sinuses, using a small guarded trocar and canula, is effective. Lambs with horns can be treated from 6 months old, others cannot be treated before they are a year old, since the sinuses are too shallow. The site of injection is on either side of the middle, in a line with the two supraorbital processes, or in horned sheep about 0·5 cm. antero-medially to the bases of the horns. The most suitable remedy for injection is a 25 per cent. tetrachlorethylene emulsion,* administering 5 c.c. into either sinus. With moderate infection fair results are obtained by intranasal injection of similar mixtures. The sheep is placed on its back and the head held at 45 degrees to the horizontal, while the remedy is slowly injected into each nostril. The sheep is then kept in the same position for another 15 seconds. Such intranasal injections also kill the first instar larvæ present there, especially if a spray is used. Cobbett† recommends, for winter treatment, 1 oz. 3 per cent. cresol soap solution per nostril applied by means of a spray with 35-45 lbs. pressure per square inch.

Prophylaxis.—Of very doubtful value is the method of applying pine-tar to the muzzles of the animals. If a better repellent is found, the method may become useful. It is usually done by feeding salt in narrow troughs

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* Mix 37·5 c.c. C_2Cl_4 with 37·5 c.c. liquid paraffin and add successive small quantities of this to 25 c.c. 30 per cent. soft soap solution, while shaking to emulsify. Finally, add 50 c.c. soft water.

† *Journ. Amer. Vet. Med. Assn.*, 97 (765): 565-575. 1940.

PLATE XII

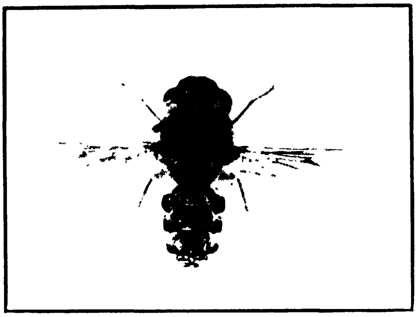

FIG. 214.—*Œstrus ovis*, FEMALE. (ORIGINAL.)

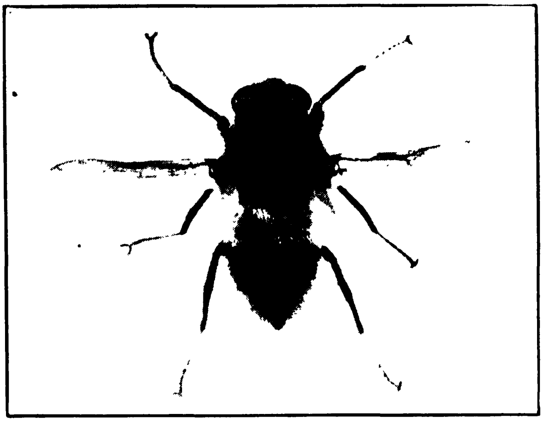

FIG. 216. *Hypoderma bovis*, MALE. (ORIGINAL.)

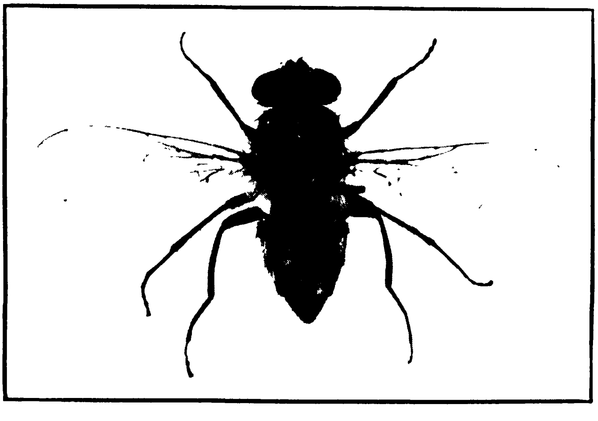

FIG. 219.—*Musca domestica*, FEMALE. (ORIGINAL.)

[*To face page* 312.

or holes drilled in logs, the edges of which are smeared with tar, so that the animals will automatically tar themselves. Such treatment has to be repeated at short intervals as long as the flies are about.

Genus **Hypoderma** Latreille

The larval stages of *H. bovis* (de Geer, 1776) and *H. lineata* (de Villiers, 1789), the "ox warbles," are common parasites of cattle, rarely also of man and horses, in many countries in the northern hemisphere and cause great economic losses. The former is the prevalent form in Europe, while the latter occurs chiefly in America. *H. bovis* is about 15 mm. long; *H. lineata* measures 13 mm. Both flies are hairy and have no functioning mouth parts. The hairs on the head and the anterior part of the thorax are yellowish-white in *H. lineata* and greenish-yellow in *H. bovis*. The abdomen is covered with light yellow hairs anteriorly, followed by a band of dark hairs, and the posterior portion bears orange-yellow hairs.

Life-Cycle.—The flies occur in summer, especially in June and July. They are most active on warm days, when they attack cattle to lay their eggs. These are about 1 mm. long and are fixed to the hairs by means of small terminal clasps, especially on the legs, but more rarely on the body as well. *H. bovis* lays its eggs singly, while *H. lineata* deposits a row of six or more on a hair. The flies are very persistent in attacking the animals, and one female may lay 100 or more eggs on one individual. The larvæ hatch in about 4 days and crawl down the hair to the skin, through which they penetrate. They wander in the subcutaneous connective tissue up the leg and then towards the diaphragm, gradually increasing in size. The larvæ of *H. lineata* find their way into the œsophageal wall, where they come to lie in the submucous connective tissue for the rest of the summer and autumn, growing to about 12 mm. in length. In the latter part of the winter the larvæ travel towards the dorsal aspect of the body and reach the subcutaneous tissue of the back. The larvæ of *H. bovis* sometimes enter the spinal canal, but usually leave it again. When the parasites arrive under the skin of the back, swellings begin to form, measuring about 3 cm. in diameter. The skin over each swelling becomes perforated, and the larva then lies with its posterior stigmal plate directed towards the pore for the purpose of respiration. This stage lasts about 30 days. The younger larvæ are almost white, changing to yellow and then to light brown as they grow older. Two ecdyses occur during the development of the larvæ. The full-grown larva of *H. bovis* is 27-28 mm. long; that of *H. lineata* 25 mm. Each segment bears a number of flat tubercles and small spines are present on all segments but the last in *H. lineata* and the last two in *H. bovis*. In spring the mature larva wriggles out of its cyst and falls on the ground, into which it penetrates to pupate. The pupal case is black and the fly emerges from it, after 35-36 days, by pushing open an operculum at the anterior end.

Pathogenesis.—When the flies approach to lay eggs the cattle become scared and attempt to escape the attack by running away, and will even go into water. Since the flies are persistent the animals are constantly irritated and do not feed properly, which results in an appreciable loss of weight and decrease of milk yield. The animals may hurt themselves severely or at least become wounded and thus damage their skins.

The larvæ irritate the tissues around them, the flesh becomes greenish-yellow and infiltrated, even along the tracks where larvæ have wandered, and thus depreciates in value. Inflammatory changes may be produced in the spinal canal and the œsophageal wall. In the latter case a proliferation of connective tissue may produce stenosis and difficulty in deglutition.

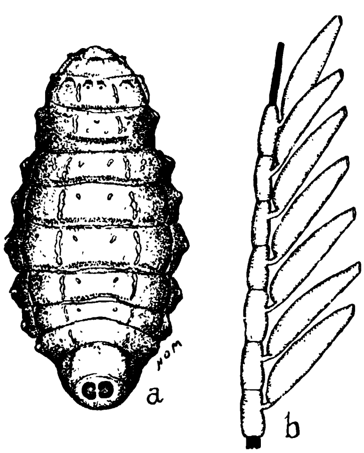

Fig. 217. — *a*, Larva of *Hypoderma bovis*, Ventral View; *b*, Eggs of *H. lineata* on Hair. (Original.)

Great damage is caused to the skin of the back by the perforations produced. The annual loss due to this factor alone is very high in some countries. It is uncertain whether the larvæ have a toxic influence on the host, but it is well known that the animals grow rapidly after the removal of the parasites. This, however, coincides with the time that the cattle are transferred from stable to pasture in the spring.

Symptoms and Lesions.—Except for poor growth in bad cases and decreased milk yield the animals show no appreciable symptoms until the larvæ appear along the back, when the swellings can be felt and seen. The larva lies in a cyst which also contains a yellow purulent fluid.

Calves and young cattle are more frequently and more severely infected than older animals. This may be partly due to the fact that the latter are more aware of the danger and know better how to escape it. Whether a certain degree of resistance or immunity develops is not definitely settled. Baudet injected young calves with larval material but obtained no immunity. Older animals may have become sensitised during previous infections by the absorption of body fluids of larvæ that die, so that they may show anaphylactic reactions when subsequently larvæ die or are broken during extraction. Even abortions have been noted in such cases. Götze states that when animals are treated with the derris wash and the larvæ die such symptoms are also seen, and he therefore does not recommend this treatment for animals over 2½ years old.

Diagnosis must be based on the presence of the larvæ under the skin of the back. The eggs may also be found on the hairs of the animals in summer.

Treatment.—Numerous remedies have been suggested and many are employed in different countries. They fall into three groups:

1. Mechanical removal of the larvæ. This may be done by applying pressure to the swellings by hand, or by means of a suction pump. The degree of success will depend on the age of the larvæ and the thickness of the skin. Not all larvæ can be removed in this way. Another method, which is much more successful, consists of lifting the larva by means of a crochet hook or similar special instrument, and extracting it with a forceps. This can be done rapidly and is the method of choice in some areas.

2. Individual treatment of each swelling by injecting or rubbing fluids or ointments into it through the pore, or inserting solid materials. Paradichlorbenzene is a common ingredient of such ointments.

3. Washing and rubbing the whole of the back with a larvicide solution. The most effective substance for this purpose is an extract made from the roots of *Derris elliptica* or Cubé root (*Lonchocarpus nicon*). The active constituent is rotenone, of which the powder should contain at least 4-5 per cent.; 1 kilo of the powder is extracted for 24 hours with 9 litres of cold water, the mixture being stirred occasionally. Then 250 gm. soft soap, dissolved in 1 litre water, is added, and the mixture should be used within a week. The back of the animal is well moistened and thoroughly rubbed, especially over the swellings. The treatment should be carried out 30 days after the first openings appear on the backs of the animals.

Whatever method of treatment is applied, an inspection for later developing larvæ is necessary after about 14 days, and these should then be removed. Anaphylactic symptoms can be treated by injection of caffein or cardiazol (10 per cent.) or calcium preparations, according to Götze.

Prophylaxis.—It will be noticed that none of the various methods of treatment in use avoid the damage caused by the larvæ, but are rather calculated to exterminate the parasite at the stage when it can be most easily reached. Prophylaxis should, therefore, aim at the destruction of all larvæ in spring. This requires a concerted and extensive campaign by all owners of cattle in a wide area in order to be successful. Davies and Jones* found that the derris wash reduced the percentage of infected cattle in one year from 90 to 15-24, and the larvæ from 11-16 to 0·5-1·1 per animal in four completely treated areas in Wales. Untreated cattle on the borders of these areas remained 90 per cent. infected. They conclude that the fly shows little tendency to migrate from one area to another.

H. æratum Austen is a similar parasite of goats and sheep in Cyprus, while *H. crossii* Patton, 1923, infects goats and sheep in India, especially in the dry, hilly regions of the North-West Provinces. The eggs are laid on the long hairs at the sides of the body and the larvæ penetrate directly through the skin, remaining there to develop for about 7 months.

Genus **Dermatobia** Brauer

D. hominis (Linné jr., 1781) (syn. *D. cyaniventris*) occurs in tropical America from Mexico to the Argentine. The female is about 12 mm. long. The thorax is dark blue with a greyish bloom, the abdomen is short and broad and has a brilliant blue colour.

Life-Cycle and Habits.—The fly sometimes lays its eggs on clothing, but more usually it attacks mosquitoes and other blood-sucking insects which it finds near warm-blooded animals, and attaches bunches of eggs to them. The larvæ are ready to hatch in about 6 days, but do so only when their carrier settles on a suitable animal to feed. Then they leave the egg-shell and penetrate into the skin. As the larva grows it produces a swelling which has a central opening through which it breathes. These swellings are usually very painful. Development in the host requires 5-10 weeks, after which the larva escapes and pupates in the ground for an equally long period before the fly emerges. The mature larva is about 25 mm. long and has a few rows of strong spines on most of the segments. Cattle, dogs, cats, sheep, rabbits and other animals may become infected.

Diagnosis.—The presence of a superficially situated swelling with a central opening, especially if more than one is present, would lead to the suspicion of myiasis. Specific diagnosis can be made only after extraction of the larva.

Treatment as for *Hypoderma* larvæ, using a suitable preparation to kill the larva and extracting it later.

Prophylaxis is difficult and should be directed against the blood-sucking insects which act as carriers for the eggs, protecting the animals against them.

Family MUSCIDÆ

Diptera which frequently have a bright metallic colour, or are grey with dark thoracic markings, or brownish with variously coloured patches. Usually not very hairy. Arista, as a rule, bilaterally plumose up to the tip. In the wing the M1 + 2 vein curves forward distally and the R5 (first posterior) cell is closed or nearly so, while the second is widely open. This family contains the non-biting *Muscinæ* (house flies), the *Calliphorinæ* (blowflies), and the important biting *Cyclorrhapha*, the *Stomoxinæ* (stable flies and horn flies) and the *Glossininæ* (tsetse flies).

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* *Journ. Ministry of Agric., London,* 39 (9): 805-813. 1932.

Sub-Family MUSCINÆ

Usually dark grey, rarely of a metallic colour. The R5 cell is closed.

Genus **Musca** Linné, 1758

M. domestica, Linné, 1758, the common house fly, has a cosmopolitan distribution, and is important as a mechanical carrier of various infectious agents such as bacteria and worm eggs, and also as intermediate host of several parasitic worms. Some other species of this genus bear a close resemblance to *M. domestica*. Male 5·8-6·5 mm., female 6·5-7·5 mm. long. The thorax is yellowish-grey to dark grey and has four longitudinal dark stripes which are equally wide and extend to the posterior border of the scutum. The abdomen has a yellowish ground colour and a median, black, longitudinal stripe which becomes diffuse on the fourth segment. In addition to this stripe the abdomen of the female is marked on either side with a diffuse dark band.

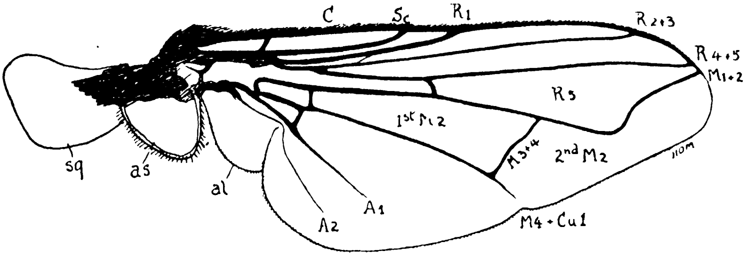

FIG. 218.—*Musca domestica*, WING. (ORIGINAL.) (Lettering as in Fig. 190.)

Life-Cycle.—The house fly lays 100-150 eggs at a time and a total of about 600. Fresh horse manure is preferred above anything else, but the fly will also develop in the fæces of other animals and man, as well as in all sorts of decaying organic matter and refuse. The eggs are about 1 mm. long, rather elongate, creamy white in colour, and the dorsal surface has two curved, rib-like thickenings. The larva hatches in 12-24 hours, and grows into a maggot 10-12 mm. long in 3-7 days. The body of the larva is pointed anteriorly, and broad at the posterior end on which the stigmal plates are situated. The distance between the two plates is less than the width of a plate and each bears three winding slits. The second body segment also bears a pair of anterior spiracles which are fan-shaped, consisting of a stalk and 5-8 papillæ each. Anteriorly the body bears a pair of oral hooks which are connected to an internal "cephalo-pharyngeal skeleton" composed of darkly pigmented chitin. Three ecdyses occur during the larval life and the pupa remains in the last larval skin, which turns brown and becomes rigid to form the puparium. The full-grown larva leaves the material in which it has developed to pupate in the ground. The pupal stage lasts 3-26 days, depending on the temperature. Fertilisation and oviposition take place a few days after emergence of the fly and the whole cycle may be completed in about 12 days, so that a number of generations develop in one summer. The adult flies live a few weeks only in summer, but they live longer in cool weather. They probably rarely hibernate. Development proceeds slowly even in winter, but flies do not emerge in cold regions. The eggs, larvæ and pupæ can resist a fair degree of cold when they lie protected, and they are responsible for the new crop of flies in spring.

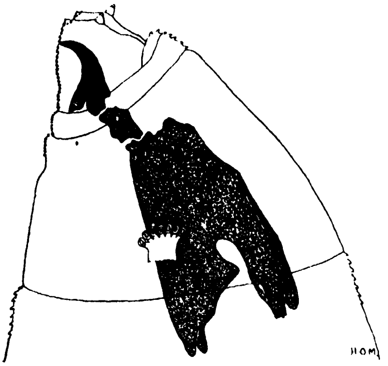

FIG. 220. — *Musca domestica*, ANTERIOR END OF THIRD-STAGE LARVA, LATERAL VIEW, SHOWING ANTERIOR SPIRACLE AND "CEPHALO-PHARYNGEAL SKELETON." (ORIGINAL.)

Habits and Importance.—The breeding and feeding habits of *M. domestica* and related species make them ready carriers of numerous pathogenic bacteria and parasites. The larval stages developing in fæces become infected with worm eggs which are present there. Pathogenic bacteria in the fæces may also be swallowed and persist through the pupal to the adult stage, but more frequently the adult fly infects itself by feeding on material which contains these organisms. The hairy feet and legs of the fly also act as suitable carriers of bacteria from material on which the fly settles. The possibility of transferring disease germs is especially great on account of the fact that flies feed on practically any edible matter, even human fæces, and also on the food of man and

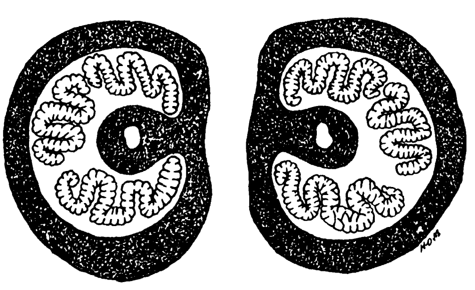

FIG. 221.—*Musca domestica*, POSTERIOR SPIRACLES AND STIGMATIC PLATES OF THIRD-STAGE LARVA. (ORIGINAL.)

animals. When the fly has fed it frequently regurgitates fluid from the crop, and it may deposit this to lick it up again later, or use it to moisten solid food like sugar. Although the house fly may frequently, though not habitually, feed on wounds, other related species are habitual blood-feeders and often follow a blood-sucking fly. When the latter has inserted its proboscis into an animal, these flies worry it until it leaves, and then they suck up the exuding blood.

The house fly and related species are known to act as carriers of several disease-producing organisms, including those of typhoid fever, cholera, tuberculosis, dysentery, anthrax and murrina (*Trypanosoma hippicum*) and the virus of poliomyelitis. *Musca domestica* is the intermediate host of several worm parasites of domestic animals, and it may act as a disseminator of the eggs of many others.

Control.—The veterinarian is mainly concerned with control measures against the breeding of flies in connection with stables, stock-yards, abattoirs, drains, garbage, etc. This becomes very important in military camps, where the occurrence of numerous flies may result in epidemics of typhoid fever and other diseases.

Manure must be regularly and frequently removed from stables, sties, etc., and transported rapidly and cleanly. Its further treatment depends on prevailing conditions, and, as it is usually valuable as a fertiliser, it must be treated accordingly; but under certain conditions this consideration has to be disregarded. Chemical treatment is usually expensive and could therefore only be applied to small quantities of manure. It is not completely effective, because the eggs and larvæ are not easily killed in this way. Moreover, such treatment reduces the fertilising value. Powdered borax well mixed with the manure at the rate of 1 kilo per cubic metre of manure (1 lb. per 16 cu. ft.) is stated to kill 90 per cent. of the larvæ and is harmless to the manure. Spraying small manure heaps with creosote, paraffin or cresol will deter the flies from ovipositing in them, but reduces the fertilising value.

A simple method of manure disposal is direct transport to a field and broadcasting thinly. This is only effective in dry, hot weather and the ground should not be moist. In dull or moist weather, or when the manure is spread too thickly, flies will still breed in it.

If manure is stacked in large compact heaps it ferments and the heat thus produced kills the maggots, as well as the eggs and larvæ of internal parasites, in the central portion of the material. The sides of the heap and the surrounding soil may be treated with paraffin or creosote or covered with leafy branches, which are then sprayed over with a fly poison. Far better, however, and practicable under most conditions, is the stacking of manure in a suitable fly-trap, of which *Baber's fly-trap* is one of the simplest. The trap is composed of four compartments, each sufficiently large to hold a week's manure. Each compartment consists of a concrete floor, sloping downward at the edges and surrounded by a gutter, which can be filled with any suitable fly poison or disinfectant. On this floor an enclosure is erected with strong posts and wire netting. The manure is packed tightly into the enclosure and moistened if it is too dry or covered in case of much rain. Fermentation in the heap will kill the maggots in the centre, while those at the edges drop into the gutter when they leave to pupate, and they are killed by the poison. In order to prevent them from escaping, the edges of the gutter should overhang slightly. Each compartment is filled in a week and the manure is left in it for 3 weeks, when it is no longer attractive for flies and can be used for fertilising.

Garbage should be collected in cans with tightly fitting lids, or the lid may overhang the top of the can and allow the entrance of flies, which are then caught in a trap placed over a hole in the lid (*Hodge's garbage can trap*). Garbage which is not used should be incinerated. If it is fed to pigs, not more should be given than can be eaten in a day.

For killing adult flies the insecticide DDT is highly effective. Dissolved or suspended in a suitable medium, it can be sprayed or painted on to walls of stables and other buildings and on to the lower leafy branches of trees around such buildings, where it will remain effective for several months.

DDT (dichlor-diphenyl-trichloroethane) is a white crystalline powder, practically insoluble in water, but soluble in various organic solvents such as benzol, toluol, carbon tetrachloride, and mineral oils, as well as in animal and vegetable oils and fats. When used as a powder—usually 5 per cent. in talc—or dissolved in mineral solvents, or as an emulsion of such solutions in organic solvents, it is highly lethal to most insects but harmless to higher animals and man. Solutions in animal or vegetable oils or fats are, however, absorbed by animals and man and are poisonous to them, so that they should never be used.

The drug is a nerve poison and is apparently absorbed through the chitinous covering of insects, especially also the pulvilli of their feet. It has not the rapid (" knock down ") action of pyrethrin, but causes a progressive paralysis, leading to death in about 30 minutes in the case of flies. It is particularly lethal to the *Diptera*, *Anoplura*, bedbugs and at least some mites, as far as the external parasites of animals are concerned, not quite so effective against adult ticks.

Apart from its efficacy as an insecticide, the great advantage of DDT is the fact that it is insoluble in water and therefore, when applied to animals or buildings, it will remain there and be effective for a long period.

PLATE XIII

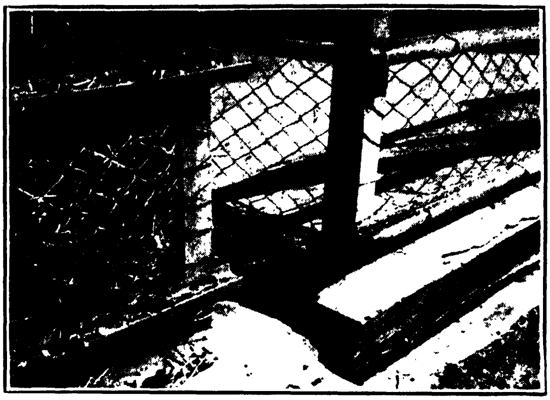

FIG. 222.—A CORNER OF BABER'S FLY TRAP.

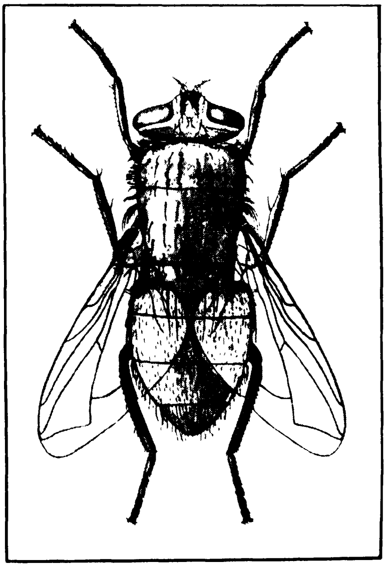

FIG. 223.—*Lucilia sericata.* (AFTER SMIT.)

[*To face page* 320.

Sub-Family CALLIPHORINÆ

This group includes the very important myiasis-producing "blow-flies" and "screw-worm flies." The adults usually have a bright metallic colour, as a rule green or blue, sometimes with brown or golden-yellow markings.

The proboscis is of the same type as in *Musca*, adapted for sucking. The flies are oviparous and lay large numbers of eggs in decomposing organic matter, carcasses, wounds, or even on the intact skin of live animals and man. The important myiasis-producing species breed only in carcasses or on live animals. In addition, these and other flies (*Sarcophagidæ*) which breed in decomposing carcasses have frequently been the cause of botulism (" limberneck ") in poultry; the maggots swallow toxins produced in the carcass by the responsible saprophytes and carry the toxins to poultry feeding on them.

The specific determination of flies of this group involves detailed morphological knowledge and is the work of specialists, but although a detailed description of the flies does not lie within the scope of this book, the veterinarian should acquaint himself with the species that are important in his country.*

Genus **Lucilia** Robineau-Desvoidy

This genus contains the most important blowflies **L. cuprina** (Wiedemann) and **L. sericata** Meigen. These are bright metallic green flies, sometimes with a golden or bronze tinge. The eyes are brownish-red. The body is relatively slender, 8-10 mm. long. The two species are difficult to distinguish: the legs are black, but in *L. cuprina* the femurs of the first pairs are bright green.

Genus **Calliphora**

C. erythrocephala Meigen and **C. vomitoria** Linné strike sheep in England; and **C. stygia** Fabricius, **C. albifrontalis** Malloch, 1932, **C. novica** Hardy, **C. augur** Fabricius and **C. fallax** Hardy, in Australia.

Microcalliphora varipes Macquart and species of *Sarcophaga* are also sheep blowflies in Australia.

Genus **Chrysomyia**

C. chloropyga Wiedemann and **C. albiceps** Wiedemann are sheep blowflies in South Africa; **C. rufifacies** Macquart and **C. micropogon** in Australia.

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* Smit, B. (1931), A Study of the Sheep Blowflies of South Africa, *17th Rep. Dir. Vet. Serv. and Anim. Ind.*, pp. 299-421. Joint Blowfly Com. (1933), The Sheep Blowfly Problem in Australia, *Rep. No.* 1, *Council for Sc. and Ind. Res. Pamphlet No.* 37.

Genus **Phormia**

P. terræ-novæ Robineau-Desvoidy, strikes sheep in Britain.

Genus **Cochliomyia** Townsend, 1915.

The palpi of these flies are short and threadlike. **C. hominivorax** (Coquerel) (syn. *C. americana*) and **Chrysomyia bezziana** Villeneuve are the " screw-worm " flies of cattle and other animals.

CALLIPHORINE MYIASIS IN SHEEP

Life-Cycle of the Parasites.—The flies lay clusters of light yellow eggs in carcasses, wounds or soiled wool, being attracted by the odour of decomposing matter. While the fly is selecting a suitable spot to lay, it feeds on the moist matter present. A female blowfly lays about 1,000 to 3,000 eggs altogether and 50-150 in one batch.

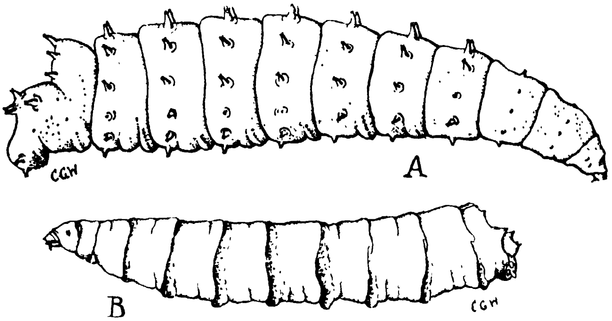

FIG. 225.—A, HAIRY LARVA OF *Chrysomyia albiceps*; B, SMOOTH LARVA OF *Lucilia sericata*. (×5.) (ORIGINAL.)

The larvæ hatch from the eggs in 8 hours to 3 days, depending on the temperature, and begin to feed. They grow rapidly and pass two ecdyses, becoming full-grown maggots in about 2-19 days. The rate of growth depends on the amount and suitability of food, the temperature and the degree of competition with other larvæ. The mature larvæ roughly resemble those of *Musca.* They are about 10-14 mm. long, greyish-white or pale yellow in colour, sometimes with a pink tinge. The anterior extremity bears a pair of oral hooks and on the broad, flattened, posterior end the stigmatic plates are situated. The second segment bears a pair of anterior spiracles as in *Musca.* Ventrally each segment, except the first one or two, is provided with a spiny pad. On the anterior segments the spines also extend around the body in the form of narrow bands. These spiny areas are used during locomotion to obtain a grip.

Two groups of larvæ can be easily recognised: " smooth " larvæ and " hairy " ones. The " hairy " larvæ bear a number of thorn-like, fleshy projections with small spines at their tips on most of the body segments. The larvæ of *Chrysomyia rufifacies*, *C. albiceps* and *Microcalliphora varipes*

PLATE XIV

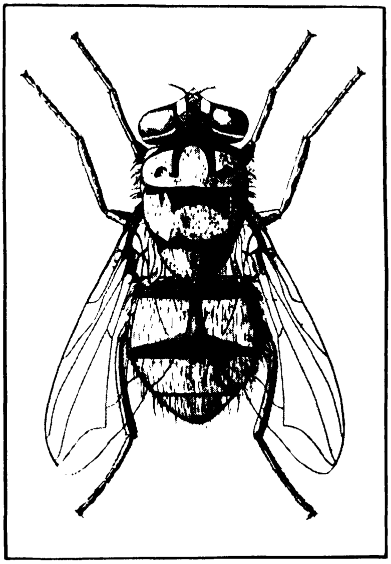

FIG. 224.—*Chrysomyia chloropyga.* (AFTER SMIT.)

are " hairy "; those of the other sheep blowflies mentioned above are smooth. The different species of larvæ can be further differentiated by means of the structure of their spiracles and the " cephalo-pharyngeal skeletons."

The mature larvæ usually leave the host or the carcass to pupate in the ground, but some may pupate in dry parts of a carcass or even in the wool of the live animal. Before pupating the larvæ may wander fair distances over or through the soil, and most species usually pupate below the surface. If conditions are not favourable, as in cold weather, pupation can be suspended for months and the larvæ may hibernate. At pupation the larva loosens its skin, which turns brown and becomes rigid to form the puparium. The pupa therefore bears some resemblance to the last larval stage; the pupæ of the " hairy " maggots retain the projections on their covering. For the rest the pupæ are slightly shorter than the mature larvæ and their ends are more bluntly rounded.

The pupal stage lasts 3-7 days in summer to much longer in winter, hibernation also occurring in this stage. The fly emerges by pushing off the end of the puparium by means of the inflated ptilinal sac, which is further used for progression to the surface of the soil. Although the females may be fertilised soon after having emerged, eggs are laid only after maturation of the ovaries, and, according to Cousin, a meal of protein food is required before this can take place. The shortest time known for completion of the life-cycle is 7 days, so that several generations can develop in one year. Smit found that nine to ten generations were completed in a year in certain parts of South Africa. The flies live a month or longer and can also hibernate.

Epizootology.—The factors which influence the occurrence of calliphorine myiasis in sheep can be classed into two groups: those controlling the prevalence of flies and those that determine the susceptibility of the sheep.

The *prevalence of flies* is seasonal, since the adults are adapted to definite ranges of temperature and to a lesser degree humidity. They are most abundant in late spring and early summer, decreasing in numbers during the hottest part of the year and again increasing in the early autumn. The different species are, however, not all alike in this respect, some preferring lower temperatures than others, and consequently a number of overlapping " waves " of different species succeed one another during the season.

The abundance and suitability of food for the adults as well as for the larvæ is of great importance. The adult flies feed on liquefied protein and on the nectar of certain plants. Since protein food is required for the maturation of the ovaries, its relative abundance greatly influences the fertility of the females. The rate of growth of the larvæ and the number that can develop also depend on the same factor.

With regard to the suitability of a carcass for the development of blowfly larvæ, Australian workers have made the following important observations: The carcass passes through several stages of decomposition and mummification, and is in each stage more attractive for certain species of flies than for others. They have thus recognised primary, secondary and tertiary blowflies, and these can be similarly grouped with respect to their activities on the live animal. The larvæ of the primary flies develop mainly during the autolytic and early bacterial stages of decomposition; those of the secondary flies develop during the subsequent stage of liquefaction and depend to a great extent on the action of the primary larvæ to produce suitable conditions for them; while the larvæ of tertiary flies (*Musca*, *Fannia*, *Peronia*, etc.), which are of little importance in connection with myiasis, follow on when the carcass begins to dry out and acquires a musty odour. In this connection also temperature and humidity are important, since they will regulate the rate of decomposition and drying out of the carcass, while the temperature also influences the rate of development of the larvæ. A dry carcass can be " rejuvenated " for the development of blowfly larvæ by a shower of rain.

The limitations in the amount of food and the time during which it is suitable for the different larvæ bring about competition between the maggots. Such competition between larvæ of the same species will result in underfed larvæ and consequently smaller flies. Competition between different species will result in a preponderance of the most successful one. The " hairy " larvæ of the secondary fly *Chrysomyia rufifacies* exert a repellent action on the primary maggots, causing them to flee, and even to desert a carcass, in spite of the presence of abundant food and space. Moreover, these maggots, as well as those of *C. albiceps*, are predatory on the primary maggots. The result of this type of competition is important, especially because the successful " hairy " maggots are of the secondary type and are not able to produce myiasis without the assistance of the primary maggots. In South Africa it has been found that the " bluebottle," *Chrysomyia marginalis*, which never strikes live sheep but breeds in carcasses only, plays a very important rôle as a competitor in carcasses. This fly is active only during the warm summer months and then it completely prevents primary sheep blowflies from breeding in carcasses, since it has a strong repellent action on their larvæ, like *C. rufifacies*. During this period the primary sheep blowflies can therefore breed on live animals only, whereas in winter, when *C. marginalis* is inactive, they are able to breed in carcasses and they build up a large population of hibernating larvæ and pupæ in the soil, from which flies emerge in spring. To this should, however, be added the fact that *L. cuprina*, which is by far the most important sheep blowfly, prefers live sheep to carcasses, and in summer, when attractive sheep are usually to be found, strikes on live sheep are a much more important source of *L. cuprina* than are carcasses, even in Australia, where there is no competition as effective as that made by *C. marginalis*.

The prevalence of blowflies is further controlled by diseases affecting them, predatory animals, parasites and carrion-eaters. The bacterial and fungus diseases of blowflies and their larvæ are not well known, but neither do they appear to have any appreciable controlling effect. Several species of birds prey on the adult flies, while ants and some carrion-beetles attack the maggots. About a dozen species of small *Hymenoptera* are known to parasitise the maggots or puparia of blowflies. Unfortunately parasitism of maggots is infrequent and the most important parasite, *Mormoniella vitripennis* (=*Nasonia brevicornis*), attacks the puparia. Since these are, however, usually located well beneath the surface of the soil they are safe, and the greatest sufferers are the secondary blowflies, *Chrysomyia rufifacies* and *C. albiceps*, which pupate rather superficially. Carrion-eating animals like vultures and hyænas reduce the amount of food of the flies and the possibilities for breeding

Local prevalence of flies depends on the general prevalence as well as on the presence of wind, suitable shelter and food. Most flies are found near water and where there is a certain amount of shade. During the warm months the flies seek a broken shade with diffused light, as between reeds, while in colder seasons they are found in the open. This is important in connection with the setting of traps. Wind assists the flies in migrating and spreads odours which attract them. The flies are able to travel several miles in the course of a few days, especially when they fly with the wind. On perceiving an attractive odour the fly will travel against the wind towards the source of the smell.

The *susceptibility of the sheep* depends on inherent factors which can be influenced by selective breeding and temporary factors which can be otherwise controlled.

Sheep are struck most frequently in the breech and around the tail, where the wool is soiled and the skin scalded by diarrhoeic fæces and by urine in the case of ewes. The major predisposing factors lie in the conformation of this region, especially narrowness of breech and wrinkling of the skin, which favour constant soiling by urine and fæces. Rams and wethers in which the sheath has a narrow opening soil the wool of this region with urine and become struck there. Rams with deep head folds or with horns lying close to the head develop a "sweaty" condition of the skin in these parts and attract blowflies.

Any other part of the body may become infected if an undressed wound is present, as the result of an accident or an operation, and such cases of myiasis are seen especially on the scrotum after castration, on the tail after docking, and on the heads of rams that have been fighting. Myiasis in the dorsal region of the body is usually due to prolonged wet weather, when the wool becomes soaked with rain and bacterial activity sets in. Length and fineness of wool are important factors in this connection. Sheep with short or coarse wool, which dries rapidly, are less commonly affected in this way than those with longer or finer wool.

Pathogenesis.—Unless a wound is present, attracting the flies and providing a suitable substrate for the larvæ, bacterial activity appears to be important in preparing favourable conditions. In wool that is kept moist by prolonged wet conditions, the yolk, wool scales and skin scales become pasty and form a suitable medium for bacteria. These then produce decomposition, an odour that attracts the flies, and probably also an exudative reaction of the skin which provides food for the young larvæ until they are able to pierce the skin. Where the skin becomes soiled by urine and fæces, it is directly affected and becomes inflamed, but even here bacteria probably assist to aggravate the condition and to attract flies.

The larvæ of the primary blowflies initiate the attack and create favourable conditions for those of the secondary flies. They secrete proteolytic enzymes which digest and liquefy the tissues of the host and then feed on this pre-digested material. Only when this stage has been reached are the secondary larvæ able to develop in the lesion. It is believed that the secondary blowflies, whose larvæ are predatory on primary larvæ, originally deposited their brood in such lesions because the primary larvæ were there to feed on, and that they themselves only later became parasites of the host animal.

Large wounds are usually produced and the larvæ, especially those of the secondary flies, may form deep tunnels in the tissues and underneath the skin. The central portion of the lesion may heal with the formation of a thick scab, while the action of the larvæ extends outwards. The smell emanating from the lesion attracts other flies to deposit eggs in it, and further batches of primary and secondary larvæ may find suitable conditions for development. The maggot-infected wounds are strongly alkaline and only alkaline wounds are attractive to blowflies.

The lesion and the parasites are irritating, and the animal consequently does not feed properly, so that it becomes poor and weak. The immediate cause of death, however, is probably a toxæmia due to absorption of toxic substances (liquefied protein ?) from the lesion, or even septicæmia.

Symptoms.—The affected sheep usually stands with its head down, but does not feed, and presents a characteristic picture, so that it can be readily noticed. It may attempt to bite the affected part. When the lesion is situated around the tail or on the buttocks, the animal will stamp or jerk the hind-legs and wag the tail. Examination shows a patch of discoloured, greyish-brown, moist wool with an evil odour. The maggots may be found in the wool attacking the skin, and they crawl away into the surrounding wool when disturbed. In later stages there is an inflamed ragged wound from which a foul-smelling liquid exudes into the wool; the larvæ are burrowing into the tissues and only their posterior extremities project. The temperature may be elevated. If the disease progresses, malnutrition and loss of milk occur and death may follow within a few days in bad cases.

Diagnosis is easily made from the symptoms and by finding the larvæ in the wound.

Treatment.—The affected part must be treated in such a way as to kill off the maggots, to promote healing of the wound and to prevent reinfection. The wool covering and surrounding the wound has to be clipped off in order to ascertain the extent of the lesion and ensure proper treatment. In doing so the majority of the maggots can be removed, and they should be killed so that the mature ones will not be allowed to pupate. Larvæ lodged in deep pockets cannot be easily removed, and it is therefore desirable that the dressing should have a larvicidal action. It should, however, not be irritant and in no way check the process of healing. In view of the fact that strikes on live animals are the most important source of blowflies, as mentioned above, and especially in South Africa, where such wounds are the *only* breeding place of *L. cuprina* in summer, it is imperative to kill all maggots found in wounds and to use a dressing which is 100 per cent. effective in this respect. The only dressing known which has this property is the " Blowfly Spray " developed in South Africa* and which consists of a mixture of neutral tar oils free of naphthalene, alcohol and small quantities of cresol, mineral oil and sulphuric acid. This dressing prevents reinfection by neutralising the alkaline wound and by promoting rapid drying and healing of the surface. In Australia a dressing known as B.T.B.,† consisting of boric acid, tar oil and bentonite, is widely used. It has fair larvicidal properties and prevents restrike through the presence of the boric aicd. No doubt DDT will become an important ingredient of such dressings for protective purposes, although it is not an effective larvicide against the mature maggots.

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* *Ond. Journ. Vet. Sc. Anim. Ind.*, 18 (1-2): 73-84. 1943.

† *Journ. Counc. Sci. Ind. Res.*, 17 (1): 1-15. 1944.

Prophylaxis should aim at (1) the protection of sheep against strike and (2) the extermination of the blowflies concerned in strike.

(1) The protection of sheep can be attained (*a*) by selective breeding in order to eliminate susceptible types, and by various treatments which tend to reduce susceptibility, such as (*b*) the fold-removal operation, (*c*) correct docking, (*d*) crutching, (*e*) chemical treatment and (*f*) attention to wounds.

(*a*) *Breeding.*—It has been clearly proved that the susceptibility of a sheep to strike depends largely on its anatomical conformation; more precisely on the conformation of its hind-quarters in relation to breech strike and the conformation of its withers in relation to shoulder strike. It has also been proved that faults in conformation such as narrowness and wrinkling in the breech can be eliminated by selective breeding without loss of wool or other good characteristics and that such breeding brings about a considerable reduction in the incidence of myiasis. Obviously this is the proper line of attack, and it should be recommended as the most important prophylactic measure.

(*b*) *Fold-removal Operation.*—This operation, started by Mules in Australia, in which the breech folds of lambs at the age of 3 weeks are cut away, developed later into a much more radical procedure which consists in removing strips of skin on either side of the tail and down the postero-medial aspects of the legs to about 3 inches below the level of the vulva in females. Strips of ½-1½ inches wide are removed, according to the degree of looseness and wrinkling of the particular case, and when the wounds heal the skin of the breech is thereby pulled tight. All lambs are treated in this way, but about 10 per cent. require a further operation a few months later in order to obtain satisfactory results. The efficacy of this measure is good, but obviously it gives short-term results and therefore cannot be compared with a proper breeding policy for the purpose of eliminating breech folds. Indeed, it militates against such a policy in that it confuses selection for breeding purposes and it can do nothing to correct a narrow breech or a drooping sacrum.

(*c*) *Docking.*—Tests carried out mainly in Australia have shown that docking the tails of lambs behind the fourth instead of the usual second caudal vertebra reduces strike appreciably. The explanation seems to be that the tail, being pressed against the body of the animal, tends to flatten out small skin folds often present on either side of the vulva and which may become soiled when they are prominent. The longer tail is also held well away from the body when the ewe urinates. Thirdly, short docking tends to produce a stump surrounded by folds—the so-called

" rose tail "—which is often struck. Another important point in docking is that the lower, bare skin should be drawn towards the body before being cut, so that it will be long, while the upper, wool-bearing skin is cut off short by drawing it out before cutting. This will produce a stump with a bare end which is not easily soiled.

(*d*) *Crutching* consists in clipping the wool from around the tail and in the breech. This is a very useful measure, tending to promote dryness in this region, and it is effective in preventing strike for 4-5 weeks under ordinary circumstances. Machine crutching is more effective than hand crutching, because the machine clips the wool shorter than the shears.

(*e*) *Chemical Treatment.*—Jetting—that is, spraying the susceptible parts of the sheep with an arsenical solution or suspension at high pressure—has been widely practised and gives fair results, usually protecting against strike for 4-6 weeks. The poison is, however, lifted away from the skin by the growing wool and, since the fly lays her eggs close to the skin, the protection afforded by jetting with arsenical mixtures does not last long.

No doubt DDT, applied in a suitable form, will produce far better results. If it is present on the skin it will kill the young larvæ soon after hatching, but, even if it is only in the wool, it will affect the female fly settling on the sheep and crawling down to the skin to lay. Experience gained at the time of writing indicates that DDT may give protection for a period of 3 months, which would be most significant in view of the importance of the live sheep as a source of blowflies, as discussed above.

(*f*) *Wounds* should be avoided as far as possible; for instance, by bloodless castration, and by docking and ear-marking when there is no danger of strike, or by treating all wounds.

(2) The extermination of the blowflies concerned in strike is a more difficult matter and many attempts have failed badly in the past, because they were based on inaccurate knowledge.

(*a*) *Carcass Disposal.*—It was formerly believed that blowflies breed mainly in carcasses and strike sheep more or less sporadically, so that effective carcass disposal should control the flies. From what has been stated above in regard to the sources of blowflies, it will be obvious that the destruction of carcasses is only important during those seasons when they are the main breeding grounds of sheep blowflies and there is little or no competition from other species. During such periods—for instance, during the winter in South Africa—carcasses should be burnt or treated with poison and buried. Burial is useless unless the carcass is thoroughly poisoned. The flies often deposit their eggs in the nostrils, ears and anus of an animal even before it is dead or, at any rate, soon after death, and ordinary burial would not stop development of the maggots nor emergence of the flies. Before burial the carcass should be well sprayed (after having been cut open) with a strong arsenical solution—about 1 per cent. sodium arsenite—or well sprinkled on all sides with arsenical sheep-dipping powder.

During the rest of the year, when the primary blowflies breed on live sheep and carcasses produce only harmless competitors such as *C. marginalis*, carcasses may advantageously be buried without poison in order to encourage the competitors.

(*b*) *Trapping* as a measure to control blowflies has proved to be of little use and has generally been abandoned, mainly on account of the fact that the primary flies, which are the important ones, are attracted by relatively fresh meat bait only and it has not yet been possible to produce a more satisfactory artificial bait. A meat bait will draw an appreciable number of primary flies for 2-3 days only and thereafter it draws mainly secondary flies. *C. marginalis* is attracted by meat baits in all stages of decomposition and traps often kill larger numbers of this species than of *L. cuprina*. Apart from the fact that it is uneconomical to renew meat baits every 2-3 days, it has been shown experimentally that a considerable number of traps per acre would be required even to reduce strike in sheep running among the traps. *L. cuprina* evidently prefers an attractive sheep to any carcass or meat bait.

(*c*) *Destruction of Maggots.*—The importance of the destruction of all maggots in strike wounds has already been stressed in the section on treatment, and it is obviously of far greater value than indiscriminate attempts at blowfly extermination, such as trapping. Combined with prophylactic DDT treatment, curative larvicidal treatment of strike wounds may have far-reaching effects on the numbers of sheep blowflies.

(*d*) *Parasites and Natural Enemies of Blowflies.*—Although much attention has been paid to biological control by means of hymenopterous parasites, which could be bred and released in large numbers, they do not appear to offer much promise of ever becoming significantly effective, even when artificially assisted.

Man has evidently upset the balance of nature by breeding fine-wooled and wrinkled sheep, which offer an attractive and safe breeding ground for certain blowflies. The natural enemies of these flies are at a disadvantage and the remedy lies in reducing the attractiveness and the safety of the sheep as a breeding ground for the fly by the means already suggested.

"SCREW-WORMS" IN CATTLE AND OTHER ANIMALS

This condition is caused by the flies *Cochliomyia hominivorax* Coq. in North and South America, and *Chrysomyia bezziana* Villeneuve in Southern Asia and Africa.

The adult *C. hominivorax* is 10-13 mm. long; its body is bluish-green, with three longitudinal dark stripes on the thorax; the head is orange-brown. *C. bezziana* is a medium-sized, stout, dark bluish-green fly with four black stripes on the præscutum; the face is orange-yellow.

Life-Cycle.—The female deposits clusters of 150-500 eggs at the edge of a wound. *C. bezziana*, and probably also *C. hominivorax*, has become so much adapted to parasitism that it breeds only in wounds and not in carcasses. The larvæ hatch in 10-12 hours and grow mature in about 3-6 days, after which they leave to pupate in the ground. The mature larvæ are about 15 mm. long and are well armed with bands of spines around the body segments. The pupal period lasts from 3 days (*C. hominivorax*) or 7 days (*C. bezziana*) to several weeks, according to the prevailing temperature. Hibernation occurs most commonly in the pupal stage.

Pathogenesis and Symptoms.—Cattle, pigs and equines suffer most frequently, but other animals, including fowls, and man may also be affected. The flies deposit their eggs in wounds resulting from accidents, castration, dehorning, branding, scalding by dips, tick bites and so forth, as well as around the vulva of cows when there is a bloody discharge, or on the navel of young calves. Most cases occur during rainy weather. The maggots penetrate into the tissues, which they liquefy and thus extend the lesion considerably. The wound develops an evil odour and a foul-smelling liquid oozes out.

Treatment and Prophylaxis.—The wound is thoroughly cleaned and the maggots should be destroyed in order to prevent them from pupating, especially in the case of *C. bezziana.* A dressing as used for myiasis in sheep may be applied, and further infection guarded against. Prophylaxis requires proper dressing of all wounds and avoiding operations, such as branding, dehorning, earmarking, etc., during the fly season. *C. hominivorax* is especially attracted by new-born animals, and it is recommended in the southern United States that breeding should be so controlled as to have no young stock born between May 1 and November 15, while the fly is most active.

Genus **Cordylobia** Grünberg, 1903

C. anthropophaga Grünberg, 1903, the "tumbu fly" or "skin-maggot fly" is a stout, compactly built fly, about 9·5 mm. long. The general colour is light brown, with diffuse bluish-grey patches on the thorax, and a dark grey colour on the posterior part of the abdomen.

Life-Cycle and Habits.—The fly deposits some 500 eggs in the sleeping-places of man and various animals, on the ground or on straw, sacking, etc., sometimes apparently also on clothing that smells of perspiration.

The larvæ hatch after 2-4 days and penetrate into the skin, where they grow mature in 8-15 days. The mature larva is about 12 mm. long, and is covered with a large number of minute spines. It leaves the host and pupates in the ground for 3-4 weeks in summer before the fly emerges.

Symptoms and Diagnosis.—The larva is situated in a swelling which is not very large—about 1 cm. in diameter—but is rather painful and has a small central opening. Of the domestic animals, especially dogs and rabbits are parasitised.

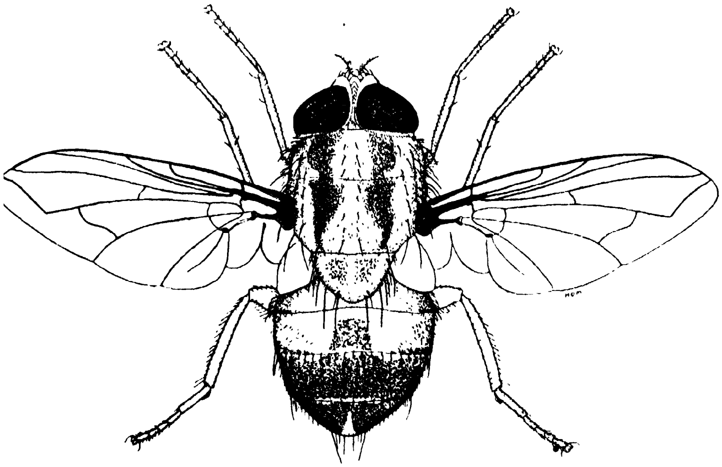

FIG. 226.—*Cordylobia anthropophaga.* (ORIGINAL.)

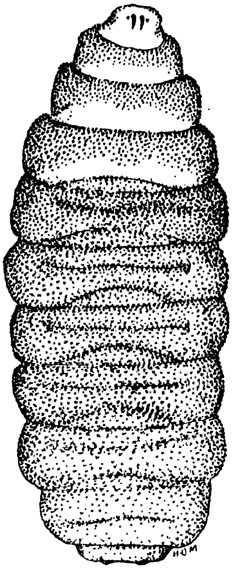

FIG. 227.—*Cordylobia anthropophaga,* MAGGOT. (ORIGINAL.)

Treatment.—The larvæ can be easily pressed out and a disinfectant applied.

Prophylaxis.—Cleanliness and regular disinfection of sleeping-places is important. In the case of valuable animals, like angora rabbits, which are frequently affected, protection can be afforded by keeping the flies out with gauze wire.

Genus Booponus Aldrich, 1923

B. intonosus Aldrich, 1923, is the "foot maggot" which attacks cattle, goats and carabao in Celebes and the Philippine Islands. The fly is about as large as a house fly, light yellow with light brown on the anterior dorsal part of the thorax. The eyes are relatively small. The head, abdomen and femora are evenly covered with short, black hairs. The veins of the wings are yellow. They are active mainly in the dry season.

The fly lays its eggs on the hairs along the coronet and the posterior part of the pastern. When the larvæ hatch they penetrate the skin in these parts and produce wounds in which the hind ends of the larvæ can be seen. After about 2-3 weeks they fall out and pupate in the ground for 10-12 days.

Affected animals are restless and show lameness, which may be serious in severe cases.

Treatment.—The maggots should be destroyed and reinfection prevented by applications as in myiasis due to sheep blowflies. The application of DDT in a suitable form is indicated as a prophylactic measure.

Sub-Family STOMOXINÆ

The proboscis is prominent, directed horizontally forwards and has small labellæ. The M1+2 vein curves gently forwards and the R5 cell is open, ending at or behind the apex of the wing.

Genus **Stomoxys** Geoffroy, 1762

S. calcitrans Geoffroy, 1764, is the commonest species of this genus and is known as the " stable fly." It occurs all over the world. The flies are about as large as *Musca domestica*. The thorax is grey and has four longitudinal dark stripes, of which the lateral pair are narrow and do not reach the end of the scutum. The abdomen is shorter and broader than that of the house fly, and has three dark spots on each of the second and third segments. The flies usually sit head upwards on a vertical surface—house flies generally face downwards—and hold their wings divergent in the resting position. The R5 cell of the wing is open.

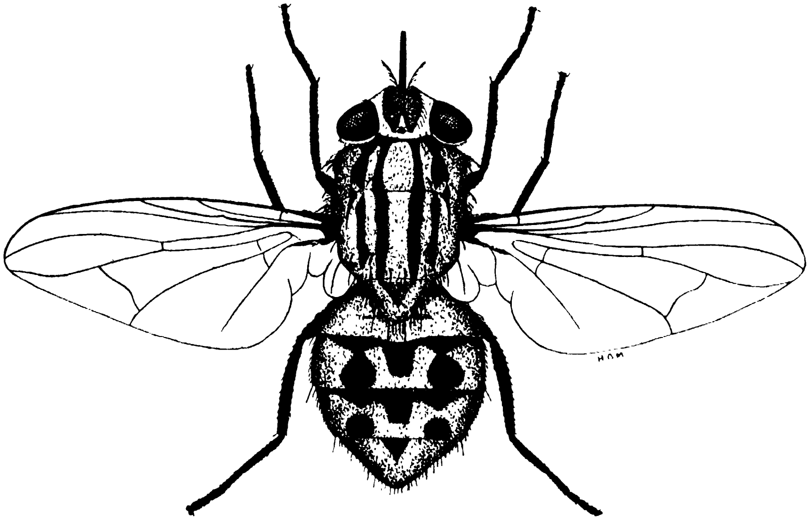

FIG. 228.—*Stomoxys calcitrans*, FEMALE. (ORIGINAL.)

Life-Cycle.—*Stomoxys* sometimes lays its eggs in horse manure, but prefers decaying vegetable matter like straw and hay, especially when these are contaminated with urine. The material must be moist, otherwise it is unsuitable. A fly lays about 25-50 eggs at a time and may lay a total of 800. The eggs are dirty-white to yellow, about 1 mm. long, and bear a longitudinal groove on one side. They hatch in 1-4 days, or longer in cold weather. The larvæ feed on the vegetable matter and in warm weather grow mature in 14-24 days. The full-grown larva resembles that of *Musca*, but its stigmal plates are far apart and each has three S-shaped slits. Pupation takes place in the drier parts of the breeding material and this stage lasts about 6-9 days, or much longer in cold weather. Oviposition begins about 9 days after emergence of the fly and after a few meals of blood have been taken. The complete life-cycle may cover about 30 days.

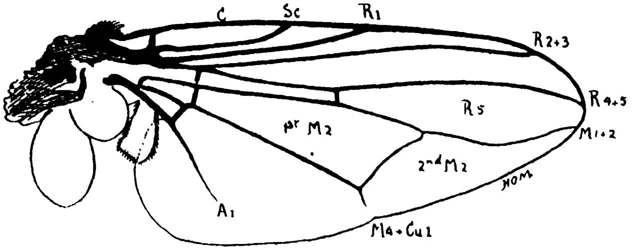

FIG. 229.—*Stomoxys calcitrans*, WING. (ORIGINAL.)
(Lettering as in Fig. 190.)

Habits and Significance.—The flies are most abundant in summer and autumn and live about a month under natural conditions. They prefer a fairly strong light, and are not seen in dark stables or houses. They enter buildings only in autumn or during rainy weather. They are swift fliers, but are not inclined to travel long distances. Both males and females are blood-suckers, attacking man, horses, cattle and other mammals, and even birds and reptiles. About 3-4 minutes are required for a meal, and the fly often changes its position or flies to another animal to continue its feed.

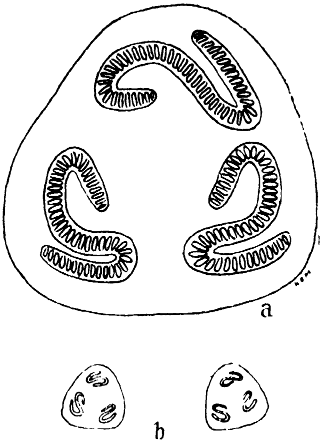

FIG. 230.—*Stomoxys calcitrans*. (ORIGINAL.)
a, Stigmal plate, much enlarged; *b*, showing relative distance between stigmal plates.

Stomoxys is known to act as intermediate host of the nematodes *Habronema microstoma* and *Setaria cervi*. It has been proved experimentally that this fly can act as a mechanical vector of surra (*Trypanosoma evansi*) equine infectious anæmia and anthrax. When the flies occur in large numbers they may become a source of great annoyance to domestic animals, resulting in decrease of milk yield and loss of weight. Sheep that have recently been shorn, as well as young lambs, are attacked along the back and suffer great annoyance. In the case of lambs the bites of the flies may become infected by bacteria, so that festering wounds and death may result.

Control.—The fly is most troublesome in localities where suitable breeding-places are readily found. Bishopp states that it is more frequent in the grain belt than elsewhere in the United States. Control measures should therefore be directed towards destroying breeding-places by regular removal of moist bedding, hay and fæces from stables and yards, and food wastes from feeding troughs, and by preventing the accumulation of heaps of weeds and vegetable refuse. Such materials can be destroyed or spread out to dry, while fæces should be treated as described in connection with the house fly. Hay or straw should be stored under cover or, if made into stacks, these should be prevented from becoming damp. The application of a suitable DDT preparation to animals will kill the flies attacking them.

Genus **Lyperosia** Rondani

Several species of this genus occur in various countries and are serious cattle pests. The most important are **L. irritans** Linné, 1758, the "horn fly," which was introduced from Europe into America and the Hawaiian Islands, where it has become a troublesome parasite; **L. exigua** de Meyere, 1903, the "buffalo fly," which occurs in the Indo-Malayan region and has been introduced with buffaloes into Australia; and **L. minuta** in Africa.

These flies are about 4 mm. long and resemble *Stomoxys* in the venation of the wings, the arista, which is plumose dorsally, and in the appearance of the proboscis. Their colour is grey with two dark broken stripes on the thorax and a few diffuse spots on the abdomen. At rest the wings overlap to about three-fourths of their width, but when the fly sits on cattle its wings are spread out more and project upwards at an angle to the body.

Life-Cycle.—The eggs are laid in the fresh dung of cattle and buffaloes. They are 1·3-1·5 mm. long and hatch in about 20 hours at a temperature of 24°-26° C. Lower temperatures retard or arrest development and the eggs are rapidly killed by drying. The larvæ burrow into the dung and feed on it, growing mature in about 4 days at a temperature of 27°-29° C. Lower temperatures prolong development considerably while higher temperatures are unfavourable. A fair amount of moisture is also required; Australian workers have found that 68 per cent. of free water is optimal for *L. exigua* larvæ and that development ceases if the moisture falls below 50 per cent. The pupæ are found underneath drier heaps or in the surrounding soil. They require about the same temperature as the larvæ and also suffer from too dry conditions. The pupal stage lasts 6-8 days.

Habits and Significance.—From the above it will be clear that *Lyperosia* is adapted to certain ranges of temperature and moisture and that it will be able to exist only in a warm, moist climate. The distribution of *L. exigua* in Australia is markedly controlled by these factors. This fly is stated to require an annual rainfall of at least 50 cm. (20 inches) and a temperature of 22° C. for permanent existence. The flies are not inclined to fly about, but remain on their hosts for several days, feeding at intervals or darting down to lay eggs when the animal has defecated. They suck blood of cattle and buffaloes, but will also attack equines, sheep and man. They are not known to transmit diseases, but are a source of great irritation to their hosts, keeping the animals from feeding and thus causing loss of condition. The animals may also rub irritated parts and so produce wounds which become septic. Cattle become used to the flies and will not suffer unless they are attacked by large numbers. Australian workers state that about 1,000 *L. exigua* per animal is the critical number.

Control.—The application of a suitable DDT preparation to the horns and backs of cattle, and if necessary to other animals, should greatly reduce the numbers of the flies, or completely exterminate them. Other animals are attacked only where cattle are present, since the fly cannot exist without cattle.

Sub-Family GLOSSININÆ

The *Glossininæ* or tsetse flies are undoubtedly the most important blood-sucking flies, since they transmit several species of trypanosomes which cause fatal diseases, known respectively as nagana and sleeping sickness, of domestic animals and man. The sub-family contains only the genus *Glossina* Wiedemann, 1830, of which about 21 species are known. These occur only in the continent of Africa, except *G. tachinoides*, which is also found in southern Arabia. The flies are narrow-bodied, yellowish to dark brown and 6-13·5 mm. long. At rest the wings are held over the back, overlapping almost completely. The width of the forehead at the vertex is about half the width of an eye in the female and one-third to one-half in the male. The proboscis is long and held horizontally, ensheathed in the long palps, which are of an even thickness throughout. The antenna has a large, elongate scape which ends in a blunt, forwardly directed point, and an arista which bears 17-29 dorsal branching hairs. The thorax frequently has a dull greenish ground colour and is marked with inconspicuous stripes or spots.

The abdomen is light to dark brown, and six segments are visible from the dorsal aspect. The venation of the wing is very characteristic, especially the course of the $M1+2$ vein. This runs obliquely backwards from its base, then bends forward to meet the very oblique anterior transverse vein, bends back sharply again towards the posterior transverse vein, and finally runs forward to reach the margin well in front of the apex. The $R2+3$ and $R4+5$ veins also turn forward at their extremities. The $R5$ cell is open. The male hypopygium—*i.e.* the eighth abdominal segment bearing the copulatory organs—lies against the ventral side of the abdomen posteriorly and appears as an oval structure with a median longitudinal groove. The structure of the copulatory organs is very important in systematic work.

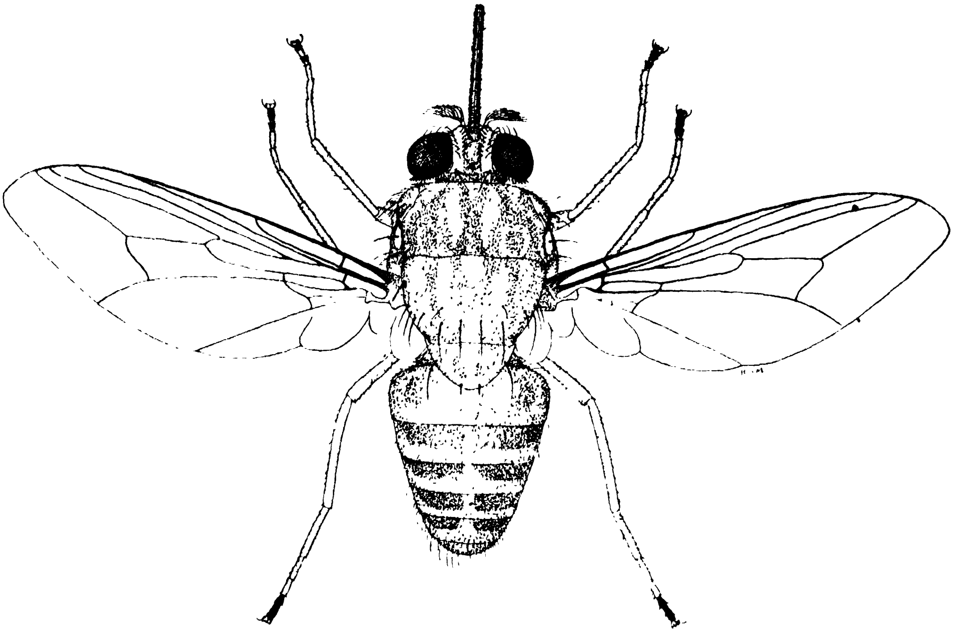

FIG. 231.—*Glossina morsitans.* (ORIGINAL.)

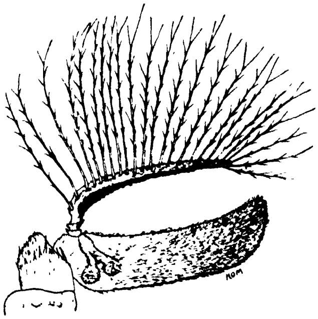

FIG. 232.—*Glossina pallidipes,* ANTENNA. (ORIGINAL.)

A description of the different species of *Glossina* goes beyond the scope of this book. The student who desires to make a further study of tsetse flies should consult the excellent handbooks of

Swynnerton,[*] Zumpt[†] and Hegh,[‡] and pick up the threads of recent literature in the *Journal of Entomological Research* or other similar publications.

Life-Cycle.—The female fly produces one larva at a time when the latter is full grown and ready to pupate. The larva grows in the uterus of the female, its mouth being attached to a " teat " from which " milk " is obtained for nourishment, and its posterior extremity, which bears the stigmal plates, lies near the vulva. The gestation period lasts about 10 days under suitable conditions, but is prolonged if food is scarce or in cold weather when the flies do not feed readily. The longevity of flies in nature is not well known, but it is estimated that a female can produce 8-10, sometimes up to a total of 12 larvæ. A female of *G. palpalis* has been kept alive under artificial conditions for 227 days, and a female of *G. morsitans* 233 days.

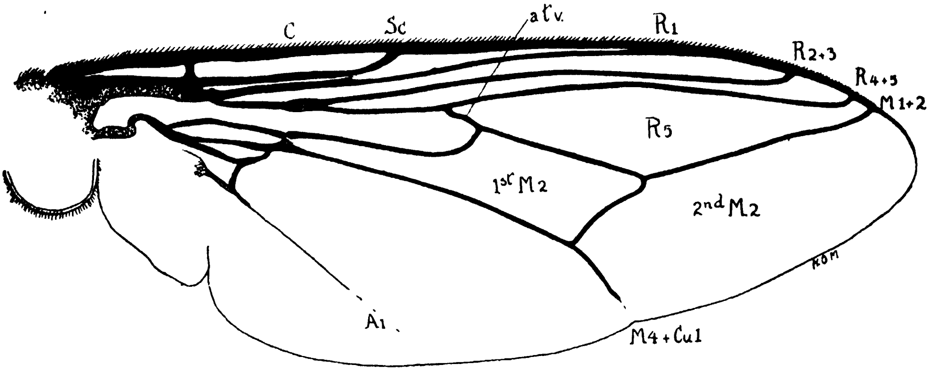

FIG. 233.—*Glossina pallidipes*, WING. (ORIGINAL.)
a.t.v., Anterior transverse vein; rest of lettering as in Fig. 190.

The larva is an oval, mobile maggot, about 7 mm. long. It wriggles into the soil to a depth of about 2 cm. and turns into a pupa after 1-1½ hours. The puparium is dark brown, or almost black, about 6-7 mm. long, and is provided with two conspicuous posterior protuberances separated by a notch which varies in size and shape in the different species. The length of the pupal period varies according to the temperature and the species concerned. It usually lasts about 35 days, with limits from about 17-90 days.

Habits.—The bionomics of tsetse flies, especially of certain species, have been extensively studied and the knowledge obtained is recorded in a vast amount of literature. It can only be attempted here to give a general impression of the most important facts.

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[*] Swynnerton, C. F. M., " The Tsetse Flies of East Africa." *Trans. Roy. Ent. Soc. London*, Vol. 84. 1936.

[†] Hegh, E., *Les Tsé-tsés.* Bruxelles, 1929.

[‡] Zumpt, F., *Die Tsetsefliegen.* G. Fischer, Jena, 1936.

Tsetse flies are found mainly in the central part of Africa, extending from the southern boundaries of the Sahara to Bechuanaland, Southern Rhodesia and Zululand. In these regions the flies are confined to definite areas known as " fly-belts," the limits of which are controlled by various factors such as altitude, moisture, vegetation and the presence of hosts. The different species vary greatly in their adaptation to environment and consequently in their distribution. *G. palpalis* occurs mainly in the areas drained by the Senegal, Niger and Congo rivers; *G. morsitans* occurs from Senegal to Abyssinia in the east and right down to Bechuanaland and Southern Rhodesia. *G. pallidipes* is essentially an East African species and is found from Zululand to Uganda and British East Africa. *G. tachinoides* can live at higher temperatures than most other species and is found in hot regions like Northern Nigeria.

The humidity of the atmosphere, the temperature and the presence of shade have an important bearing on the life of the fly. *G. palpalis* requires an almost saturated atmosphere and much shade, and is therefore found near water, especially along the banks of rivers or lakes surrounded by overhanging trees or bushes. It is killed within a short time by direct sunlight and by temperatures over 30° C., especially if the humidity is not high. Its natural range from water is about 30 metres, but the fly will follow a host for 300 metres or sometimes more away from water. *G. morsitans* and *G. pallidipes* are much less restricted to moisture and shade conditions and are most active in a moderately dry and warm climate They occur in open "park-land" type of vegetation. *G. pallidipes* requires a moderate degree of humidity, and is less independent of cover than *G. morsitans*. Both these species require trees or scrub for shelter and the former especially does not venture far into open country.

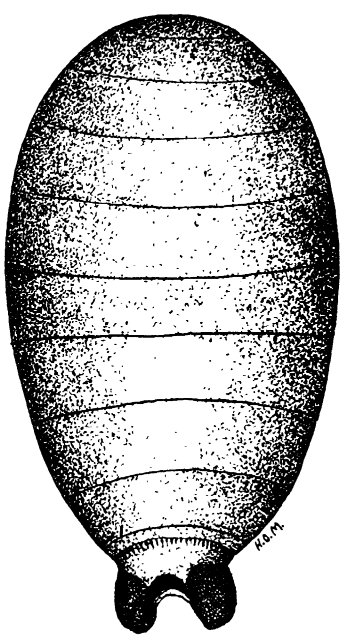

FIG. 234.—*Glossina pallidipes*, PUPA. (ORIGINAL.)

The different species are each particularly associated with certain types of vegetation, an important factor which requires much further study. The vegetation as well as other controlling factors like the presence of water restrict the flies during bad seasons to certain areas known as "primary fly centres" or permanent haunts, from which they migrate outwards along suitable courses to temporary haunts during favourable seasons. *G. palpalis* will, for instance, ascend to the upper limits of rivers in rainy seasons and again descend when dry conditions set in. The recognition of these facts is very important in connection with control measures.

All the species of *Glossina* feed on the blood of vertebrates. *G. tachinoides* feeds on its dead mates in captivity and may therefore, perhaps, also feed on insects in nature. Some species of hosts are more suitable than others, and the prevalence of flies is dependent on the number and suitability of hosts. *G. palpalis* thrives best on the blood of warm-blooded animals and is stated to prefer human blood, but it can also feed on cold-blooded animals like crocodiles. It is generally agreed that this species is not dependent on big game for its existence. *G. morsitans* feeds on any large mammal or bird, but is not able to exist permanently where big game or cattle are absent. This fly disappeared from the Transvaal with the big game which was killed out by rinderpest. It has been proved that the fly itself is not susceptible to rinderpest. Occasionally *G. morsitans* has been found where big game was scarce, but since the pupal period is long, such flies may have emerged some time after the main stock of flies left the particular area. *G. pallidipes* is similarly dependent on big game or cattle for its existence, but warthogs are an important source of food for both species.

The flies fly low near the ground and hunt by sight. They are susceptible to the effects of light and shade and are attracted especially by moving objects. As a rule they prefer to bite on dark surfaces, probably being attracted by them just as they are attracted by a shadow. While it is being attracted by or following a host, the fly will leave its natural haunts and cover for variable distances, depending on the species of fly and the prevailing conditions. *G. palpalis* is attracted to boats moving on a river and *G. morsitans* may attack animals or human beings several hundred metres away from its bush cover. In this way the fly may reach new sites after leaving its host or after giving up the chase. When the host stops moving the fly, especially *G. palpalis*, is apt to leave.

The flies feed about every 3 days, depending on the temperature and humidity. In a humid atmosphere longer starvation is possible, while a higher temperature shortens the interval. Most species are active in the forenoon and afternoon, disappearing during the hottest hours of the day. Some, like *G. brevipalpis*, are nocturnal in their habits, feeding especially on moonlight nights, but even others may attack hosts around a camp fire at night. Rain or windy weather causes the flies to remain in shelter.

The hungry fly is alert and is stimulated to fly from its bush cover by the scent of an animal. The fly is drawn by the scent and the horizontal bulk of the animal's body, and it usually settles on the legs of the animal to feed, sometimes on the lower aspect of the abdomen. If it is disturbed there, it may settle on another part of the body. As the fly engorges, its abdomen becomes much distended. Finally the fly leaves its host and settles on the under-side of a leaf or a log or on the bark of a tree to rest. Soon a drop of dark fluid is voided through the anus, then several drops of clear fluid, and sometimes also a drop of fresh blood, which then fills the gut.

Towards the end of the gestation period the females do not feed but remain in shelter. For this reason, and also because the males frequently approach a host in search of females, the number of males usually predominates in a catch of flies taken in the vicinity of a host. Unsuitable food or starvation may cause the female to abort, and occasionally pupation occurs in the uterus and is invariably fatal to the fly.

The breeding-places of tsetse flies are carefully chosen and they are restricted by various factors. *G. palpalis* deposits its larvæ usually not more than 25 metres from water and about a metre above water-level in dry, coarse sand or in humus around tree trunks, in forks of branches and cracks of bark up to 4 metres high above the ground. *G. morsitans* and *G. pallidipes* breed in loose, sandy soil rich in humus on sheltered and well-drained spots, usually near game paths where the flies abound. The pregnant female about to deposit a larva is attracted by objects which provide shelter, like fallen tree trunks or slanting rocks, and deposits the larva underneath them. Shade is essential to the pupæ even though they lie covered in the soil. A few hours of sunshine per day rapidly kills them.

Natural enemies of the tsetse flies do not appear to play an important part in nature, although the pupæ are frequently parasitised by small Hymenoptera and the flies themselves may be caught by predatory wasps and birds. *G. morsitans* appears to be fond of feeding on baboons and the flies will follow the animals, but it has been noticed that the baboons catch the flies which attack them, and they are therefore rather destructive to the fly than a source of food which should be eliminated.

GLOSSINA AND DISEASE

Most or all of the species can serve as intermediate hosts of various trypanosomes. The most important and best known are *G. palpalis*, which transmits human sleeping sickness caused by *Trypanosoma gambiense* and nagana of domestic animals caused by *T. brucei*, *T. congolense* and

T. vivax; *G. morsitans*, which transmits the sleeping-sickness parasite *T. rhodesiense* and the nagana trypanosomes; and *G. pallidipes*, which also transmits the latter parasites. The infection may be transmitted mechanically if the fly passes from one host to another during its feed, but this probably does not happen frequently in nature. Only a small proportion of flies become infected by feeding on an infected animal. The reasons for this occurrence are not fully known, but the interval before the next feed and the temperature may be important factors. If the interval is short, the trypanosomes may be washed out of the digestive tract of the fly before they have developed far enough to invade the body, and a low temperature arrests their development in the fly.

Some species of trypanosomes are mainly spread by one species of *Glossina*, as, for instance, those mentioned above, but the receptivity of a species of fly for a particular trypanosome is perhaps not equal in all localities, so that the most important vector may not be the same everywhere.

Control.—The control of tsetse flies is probably one of the most widely studied problems of veterinary and medical entomology, but yet leaves much to be discovered. The following are the most important measures:

1. *Bush-Clearing.*—In the case of flies like *G. palpalis*, which require much shade, this measure is important and the clearing of bush around settlements, wells, landing-places and fords on rivers and on either side of roads has given excellent results in providing protection from the fly. Wholesale clearing of large areas, however, presents many difficulties, especially the expense incurred and the rapid regrowth of the bush. Only if clearing is followed by settlement can the advance be maintained. Moreover, clearing of certain types of soil leads to soil erosion and the clearing of very large areas might have an adverse effect on the rainfall.

In the case of flies like *G. pallidipes* and even *G. morsitans*, which are more independent of cover, bush-clearing is not so expedient, and attempts have even been made to erect barriers against such flies by planting broad strips of dense thickets, in which they cannot live.

Bush-clearing has been applied in various other ways, especially in the form of strip-clearing, by means of which an area can be divided into sections for fly control and reinfection of cleared areas can be prevented. Shircore has recommended strip-clearing in order to isolate the permanent fly centres, which could then be cleared.

2. *Late burning* of large areas, if properly organised and carried out for a number of years in succession, as recommended by Swynnerton, is of great value in reducing the number of flies. A good stand of dry grass and a strong wind are required. Large established trees do not suffer, as the fire passes rapidly, but many pupæ also escape being killed.

The game is driven out to surrounding areas, but returns fairly soon, and many flies may find effective shelter in the green vegetation of river banks and streams. In spite of these and other difficulties, however, the method is a valuable one in localities where it can be applied.

3. *Destruction and control of big game*, though not of importance in the case of *G. palpalis*, is definitely effective against other species that require these hosts for food. Marked reduction of the fly has followed organised shooting of big game in certain areas. According to Jack, reduction of the fly must be attributed not only to the reduction of their food supply, but also to the fact that the remaining animals change their habits in such a way as to break up their association with the fly. The latter is consequently not able to obtain its meals with that regularity and frequency which is required for breeding and continued existence. Possibly this is also an important result of human settlement, which is known to cause a reduction of flies like *G. morsitans*.

In connection with game destruction the importance of warthogs and bushbuck as a source of food for *G. pallidipes* and *G. morsitans* should be borne in mind and these species of " small game " should also be effectively destroyed. This is impossible to achieve in densely wooded parts, so that bush clearing and game destruction must be combined in such areas.

Objections against game destruction are frequently raised by the public, but it must be realised that measures other than game destruction against the savannah bush tsetses, such as *G. morsitans* and *G. pallidipes*, have been successful only where they have been favoured by local and unusual natural or human factors. In general, however, game destruction has been the only single successful measure. It remains to be seen whether the use of DDT on a large scale may not provide a better alternative.

Successful attempts have been made to control the movements of big game by the erection of high fences as barriers. In this way successive strips of country can be cleared of game and fly, if clearing is followed or preceded by the erection of a new fence.

4. *Catching and trapping* have been tried as a means of extermination on account of the limited reproductive activity of tsetse flies. Catching with hand nets is not practicable except in small areas. It is the common method of determining the fly density in a given locality, the density being usually stated in terms of the number of flies caught per hour.

Numerous types of traps have been designed, mainly on the principle that the fly is attracted by a horizontal shadow and flies in underneath it. The traps cast such a shadow and catch the flies in a cage, into which they are drawn by light falling through from the top.

For many years the Harris trap has been used in Zululand. Thousands of these traps were set in the game reserves, where the flies are concentrated, and enormous numbers of flies were killed in this way. Yet the point of extermination has not been reached. Gradually it became clear, and was proved experimentally, that the scent of an animal is required to activate the fly and that scent plays a more important part in attracting the fly than does the sight of a horizontal shadow. In comparison to game the trap is therefore at a disadvantage. If no animals are present the flies are rather inactive and catches are low; the presence of animals activates the flies and, although catches are then higher, the moving animals are more attractive than the stationary traps and also draw flies on account of their scent. A large number of flies will feed on the animals and stop hunting. The trap therefore catches only a small percentage of the flies in its vicinity and can never exterminate the flies in the presence of game, whereas, if the game is destroyed, there will be no need for traps.

5. *Artificial breeding-places* may be valuable additional aids to reduce the flies, where the natural breeding-places are limited in number. Attractive sites are made under logs, rocks or planks, and the pupæ are regularly removed or the covering object is placed in such a way that the pupæ may be killed by the sunlight.

6. *Repellents* for application to stock have not been successful and there is very little prospect of developing practical measures on these lines.

7. *Poisoning.*—The discovery of DDT opens up a new avenue of attack on tsetse flies and presents a possible method of total eradication. A suitable technique of applying the insecticide has still to be found, but aeroplane dusting suggests itself, perhaps combined with aerosol spraying.

PUPIPARA

The *Pupipara* are a group of aberrant *Diptera*, related to the *Muscidæ*. They are markedly adapted to a parasitic life. All the species, with one exception, live on the blood of mammals or birds. The body is broad and flattened dorso-ventrally; the abdomen is indistinctly segmented, and usually its wall is soft and leather-like. Wings are present in some species and absent in others. The antenna has one joint and lies in a pit on the forehead. The feet are provided with strong claws, by means of which the parasite clings to the hairs or feathers of its host. As the name *Pupipara* indicates, the females give birth to larvæ which are ready to pupate.

Family HIPPOBOSCIDÆ

Genus **Hippobosca** Linné, 1761

Several species of this genus, especially **H. equina** Linné, 1758, **H. rufipes** Olfers, 1816, and **H. maculata** Leach, 1817, are common parasites of horses and cattle, particularly in warm countries. Other animals like dogs may also be attacked. The flies are about 1 cm. long to the tip of the abdomen and have a reddish-brown colour with pale yellow spots. There are two wings, the veins of which are crowded together towards the anterior border. The short, thick palpi ensheath the tip of the slender proboscis, of which the main portion is withdrawn into the head during rest.

Life-Cycle and Habits.—The female fly deposits one larva at a time in sheltered spots where there is dry soil or humus. Roberts found in Wales that *H. equina* lays in humus at the roots of certain plants, mainly bracken (*Pteris aquilina*). The larvæ pupate almost immediately, and gradually turn from yellow to black. The larva is subglobular in shape; it measures about 5 by 4 mm. and possesses a dark spot at the posterior pole. The length of the pupal period is greatly influenced by the temperature. The flies are most frequent in summer and bite more particularly in sunny weather. They remain for long periods on their hosts and are not easily disturbed. They cluster in the perineal region and down between the hind-legs to the pubic region, but may also bite on other parts of the body. Distribution occurs almost exclusively with cattle and horses, since the flies are not inclined to travel more than a few metres, although they are strong fliers. These flies are a source of great irritation to animals which are not accustomed to them. They transmit the non-pathogenic *Trypanosoma theileri*, and there is little doubt that they are important mechanical carriers of anthrax, especially in the case of horses with anthrax swellings.

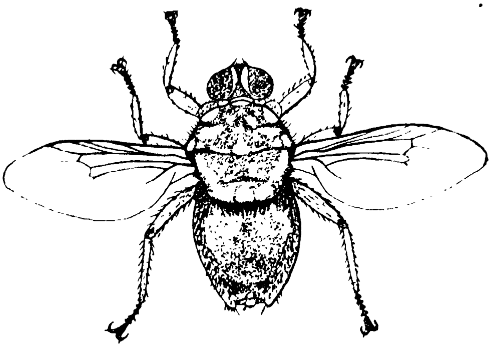

FIG. 235.—*Hippobosca rufipes.* (AFTER BEDFORD.)

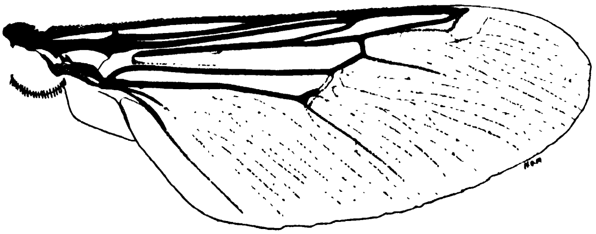

FIG. 236.—*Hippobosca rufipes*, WING. (ORIGINAL.)

Control.—The flies can be readily killed by applying DDT to those parts of animals where they congregate.

H. capensis v. Olfers (syn. *H. francilloni*) occurs in Africa and Asia and attacks chiefly dogs.

Genus Melophagus Latreille, 1804

M. ovinus (Linné, 1758), the "sheep ked," is found in most parts of the world. It is a wingless, hairy, leathery insect, 4-6 mm. long. The head is short, broad and not freely movable; the thorax is brown and the broad abdomen greyish-brown. The legs are strong and armed with stout claws.

Life-Cycle and Habits.—The female attaches its larva to the wool of the sheep by means of a sticky substance. Parturition lasts a few minutes.

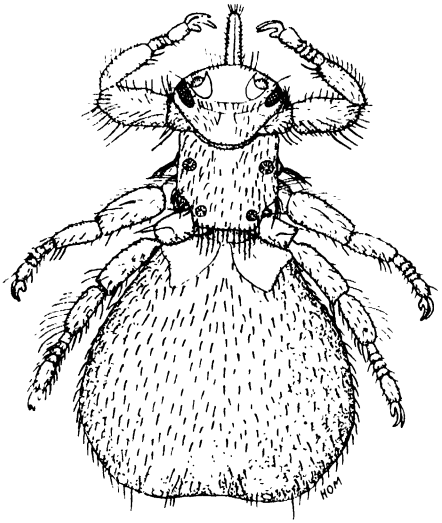

FIG. 237.—*Melophagus ovinus*, ADULT. (ORIGINAL.)

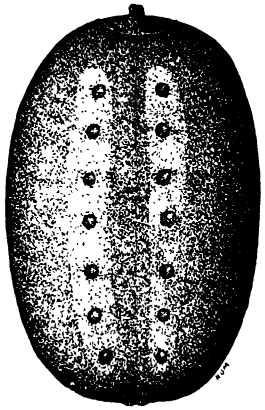

FIG. 238.—*Melophagus ovinus*, PUPA. (ORIGINAL.)

The larva is immobile and soon turns into a chestnut-brown pupa. It is ovoid in shape with broad ends and 3-4 mm. long. The pupal stage lasts 19-23 days in summer to 36 days in winter, or even longer if the sheep are exposed to very cold conditions. The female ked lives 4-5 months on a sheep. Copulation occurs 3-4 days after emergence of the adult and each gestation lasts about 10-12 days. A female may produce 10-15 larvæ. Engorged females can live up to 8 days off the host. Pupæ removed from the sheep, for instance at shearing, can hatch if conditions are favourable, but the emerging adults die very soon if they do not find a sheep to feed on. The parasites occasionally leave a sheep and may be found on the floor of sheep-pens or stables, but they are usually spread by direct contact of the hosts.

Pathogenesis.—The parasites live in the wool of the sheep and suck blood. Heavy infections can reduce the condition of the host considerably and even cause anæmia. They produce intense irritation, causing the sheep to bite, rub and scratch itself, thus damaging the wool, and the sheep may acquire the vice of wool-eating. The fæces of the keds produce stains in the wool which do not wash out readily. The ked transmits *Trypanosoma melophagium*, a harmless blood parasite of sheep. Poorly fed animals or animals that are not protected against cold weather are most liable to suffer from keds, so that the parasites are particularly troublesome towards the end of winter.

Control.—DDT is very effective against keds and one application of it in a suitable form should suffice to kill the parasites as well as those subsequently emerging from pupæ present on the animals. Rotenone is also effective and one application may suffice, but if arsenical dips are used, three dippings are required in order to kill the emerging parasites before they are able to produce new pupæ and to cover the whole period the pupal stage may last. Carbolic, nicotine and polysulphide dips are ineffective.

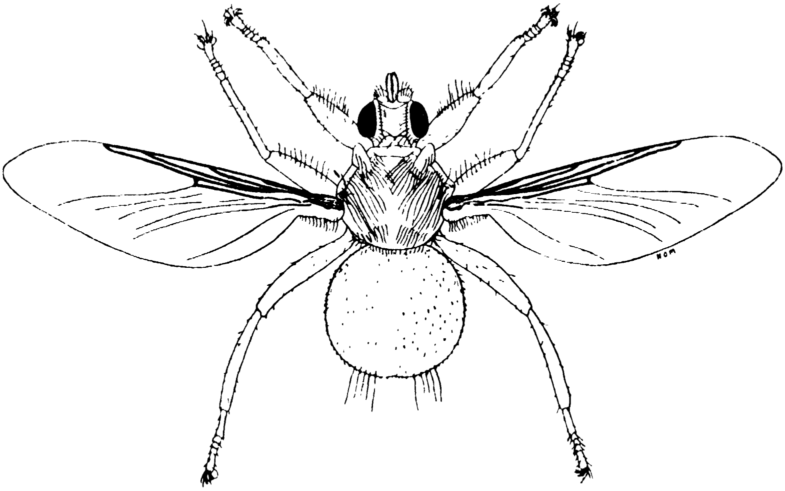

FIG. 239.—*Pseudolynchia canariensis.* (ORIGINAL.)

Genus **Pseudolynchia** Bequaert, 1925

P. canariensis (Macquart, 1840) (syn. *maura*) is a fly which resembles the sheep ked, but has a pair of transparent, tapering wings with the venation reduced and concentrated along the anterior border. The claws are strong and spurred. The parasite is widely distributed in warm countries and lives on domestic pigeons and a few wild birds.

Life-Cycle and Habits.—The flies suck blood, especially on young nestling pigeons 2-3 weeks old, when the feathers begin to grow and afford protection. When the bird is handled the parasites fly away and they are not easily caught. Copulation takes place on the host and the larvæ are laid in dark crevices of the pigeon-house in dry dust or in the nests, if these are suitable. The larvæ are yellow with a dark posterior pole and measure about 3 by 2·5 mm.; they turn into black pupæ in a few hours. The pupal stage lasts 23-31 days in warm weather. The parasite transmits *Hæmoproteus columbæ*, a blood protozoon of pigeons.

Control.—The flies on nestling pigeons can be killed by means of DDT or pyrethrum powder; sodium fluoride and sodium fluosilicate are not so effective according to Bishopp. Such treatment is, however, not effective in the case of adult birds that fly about. The best measure is regular and thorough cleaning of the nests and all other parts of the pigeon-houses at intervals of 3 weeks, destroying the collected pupæ.

Order HEMIPTERA

This order includes a large number of plant lice and bugs of considerable economic importance. Only a small number of species are blood-suckers and of medical importance.

Genus **Cimex** Linné, 1758

Several species of this genus, of which *C. lectularius* Linné, 1758, the bed-bug, is the best known, attack man and animals to suck blood. The parasites are 4-5 mm. long, flat-bodied, elongate oval in shape and yellowish-brown to dark brown in colour. The head bears a pair of long antennæ with four joints, of which the first is short and the third and fourth are slender. The compound eyes project conspicuously at the sides of the head. The prothorax is large and deeply notched anteriorly where the head is inserted in it. The wings are vestigial. The abdomen has eight visible segments. The whole body is covered with characteristic spinose bristles and some hairs. The tibiæ of the legs are long and the tarsi have three joints. The adult has a pair of ventral thoracic stink glands and the young stages have similar dorsal abdominal glands. These glands are responsible for the characteristic odour of the insect.

*Life-Cycle and Habits.**—The female lays about 150-200 eggs in dark crevices. The egg is creamy white, about 1 mm. long, and has an operculum with a thick rim at one pole. The larva hatches after 3-14 days at 23° C. or longer at lower temperatures and resembles the adult. There are five nymphal stages. The rate of development depends greatly on the food supply and the temperature. Under favourable conditions the adult stage is reached in 8-13 weeks after hatching.

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* See Johnson, *Journ. Hyg.*, 41 (4): 345-461. 1941.

The bugs live long and can survive long periods of starvation; adults have been kept without food for over a year. The insects live in crevices and cracks of wood near the sleeping-places of their hosts; for instance, in bedsteads or behind picture-rails and skirting-boards, or in the nests or perches of poultry. They are mainly nocturnal insects, but will bite sitting hens also in the daytime. After a meal the bug defecates and usually turns round in such a way that its fæces fall on or near the wound, thus providing the possibility for transmission of disease through its fæces. Bugs may travel relatively long distances, passing to adjoining houses from an infected one.

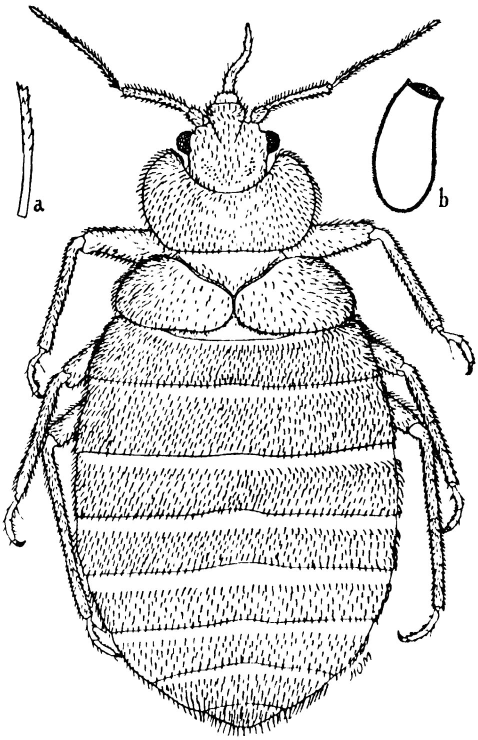

Fig. 240.—*Cimex lectularius*, Dorsal View. (Original.)

a, A bristle; *b*, egg.

Apart from being very annoying insects in human dwellings, several species of bugs at times cause severe irritation and anæmia in poultry, especially fowls, turkeys and pigeons. Besides *C. lectularius*, other species of this genus and *Ornithocoris toledoi* Pinto, 1927, which occurs in Brazil, are known as poultry parasites.

Control.—The parasites are best exterminated by means of DDT applied in powder form or as a spray.

Order ANOPLURA

This order includes the biting and sucking lice. They are small, wingless insects with short legs and antennæ. The body is flattened dorso-ventrally. The lice live as permanent ectoparasites on mammals and birds. The females attach their eggs to the hairs or feathers of the host and the young lice resemble the adult.

Sub-Order MALLOPHAGA

This group contains the biting lice, which are characterised by their broad, flat heads, usually rounded anteriorly, and the mandibulate mouth parts which are situated on the ventral side of the head. All the bird lice and also some mammalian lice belong to this group.

The most common poultry lice are the following:

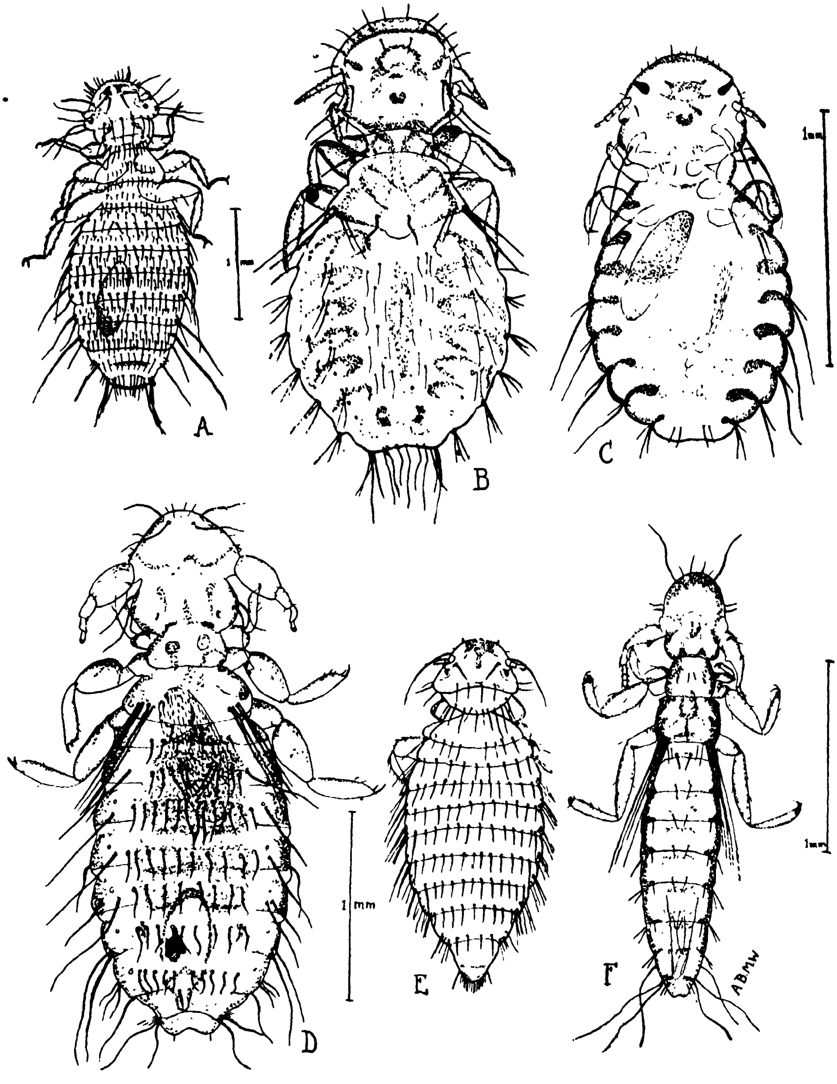

FIG. 241.—COMMON FOWL LICE. (ORIGINAL.)

A, *Eomenacanthus stramineus*; B, *Goniocotes gigas*; C, *G. hologaster*; D, *Lipeurus heterographus*; E, *Menopon gallinæ*; F, *Lipeurus caponis*.

Menopon gallinæ (Linné, 1758) (syn. *M. pallidium*), the "shaft louse," is pale yellow in colour. Male 1·71 mm., female 2·04 mm. long. The thoracic and abdominal segments have each one dorsal row of bristles. Occurs on fowls, according to Piaget also on ducks and pigeons, and moves about rapidly. The eggs are laid in clusters on the feathers.

M. phæostomum (Nitzsch, 1866) occurs on the peacock.

Eomenacanthus stramineus (Nitzsch, 1874) (syn. *Menopon biseriatum*) is the yellow "body louse," occurring on the skin of those parts of the body which are not densely feathered like the breast, thighs and around the anus. Male 2·8 mm., female 3·3 mm. long. The abdominal segments have each two dorsal rows of bristles. The eggs have characteristic filaments on the anterior half of the shell and on the operculum, and are laid in clusters on the feathers near the skin. Occurs on the fowl, turkey, peacock and Japanese pheasant, and is especially harmful to small chicks.

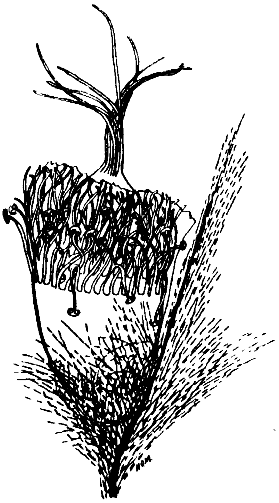

FIG. 242.—*Eomenacanthus stramineus*, EGG ATTACHED TO FEATHER. (ORIGINAL.)

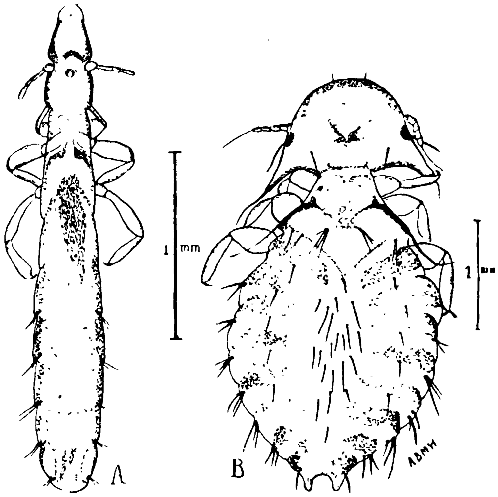

FIG. 243.—A, *Columbicola columbæ*; B, *Goniodes meleagridis*. (ORIGINAL.)

Lipeurus heterographus Nitzsch, 1866, the "head louse," occurs on the skin and feathers of the head and neck. Male 2·43 mm., female 2·6 mm. long. In the male the first segment of the antenna is long and thick, bearing a posterior process. The abdomen is elongate in the male and barrel-shaped in the female, with dark-brown lateral tergal plates. The eggs are laid singly on the feathers. Occurs on fowls and partridges. It is a dangerous parasite of chicks.

L. caponis Linné, 1758, the "wing louse," is a slender, elongate louse which occurs on the under-side of the large wing feathers and moves about very little. It occurs on fowls and pheasants.

Goniocotes gigas Taschenberg, 1842, is a large louse occurring on the body and feathers of the fowl. Male 3·2 mm., female 5 mm. long.

G. hologaster Nitzsch, 1838, the "fluff louse," occurs in the fluff at the bases of the feathers. It is a small louse; the male is 1 mm. long and the female 1·6 mm. The body is broad and the head short and wide. Occurs on fowls, pheasants and pigeons.

Goniodes meleagridis (Linné, 1758) is a common louse of the turkey, and **Columbicola columbæ** (Linné, 1758) (=*Lipeurus baculus* Nitzsch) occurs on domestic and wild pigeons.

The common biting lice of domestic mammals are:

Bovicola bovis (Linné, 1758) (=*Trichodectes scalaris*) on cattle.

B. equi (Linné, 1758) (=*Trichodectes parumpilosus*) on equines.

B. ovis (Linné, 1758) (=*Trichodectes sphærocephalus*) on sheep.

B. capræ (Gurlt, 1843) (=*Trichodectes climax*) on goats.

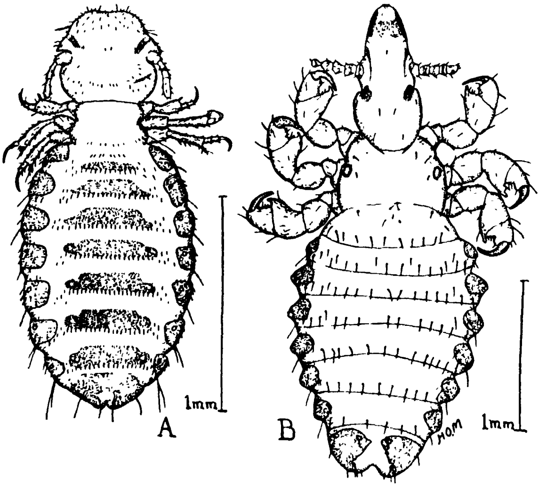

Fig. 244.—Lice of the Horse. (Original.)
A, *Bovicola equi* ; B, *Hæmatopinus asini*.

B. painei (Kellogg and Nakayama, 1914) on goats.

B. limbatus (Gervais, 1847) on angora goats.

Trichodectes canis (de Geer, 1778) (=*T. latus*) on dogs.

Heterodoxus longitarsus (Piaget, 1880) on dogs, kangaroos and wallabies.

Felicola subrostrata Nitzsch, 1838, on cats.

Life-Cycle and Habits.—The eggs are attached to the hairs or feathers of the host and require the warmth of the body to hatch. Under suitable conditions hatching occurs after 5-8 days and the young lice moult three to five times, according to the species, before the adult stage is reached after 2-3 weeks.

The lice cannot exist off their host for more than a few days, but they rarely leave their host spontaneously. The infection is therefore spread mainly during close contact of the hosts. The *Mallophaga* feed on epidermal scales, bits of feathers, or hairs and exudations of the skin. Blood has been found in their alimentary canals on several occasions and Ries* found Rickettsias in *Eomenacanthus stramineus.* The blood may have been ingested from small wounds on the animal. Kotlán,† however, considers that certain species of *Mallophaga* are able to draw blood from the unbroken skin and that they are not as harmless as is generally believed.

PEDICULOSIS IN POULTRY

All poultry lice are biting lice and the most important are the " head louse " and the " body louse " on young chicks, which may kill their hosts. A few lice are not significant, but under suitable conditions their numbers may increase rapidly. They irritate their hosts so that these are restless and neither feed nor sleep well. The egg yield decreases and the plumage of the birds may become damaged.

Control.—If possible the lice should be killed without disturbing the birds, and this is best done by painting the perches in the fowl-house with strong tobacco extract containing 40 per cent. nicotine, using about 400 gm. for every 50 metres (½ lb. for 100 feet). The fowl-house should be closed at the back and sides, but only partly closed in front, so that the fumes will not be too strong for the birds. All the birds should sleep in the building on the following two nights. The warmth of their bodies causes the nicotine to evaporate and to kill the lice. Most or all eggs are also killed, but a second treatment may be necessary 10 days later.

For dusting birds to kill lice a small quantity of a DDT powder (about 5 per cent.) is placed between the feathers on various parts of the body.

The biting lice of mammals are treated like the sucking lice.

Sub-Order SIPHUNCULATA

The sucking lice are flattened dorso-ventrally, oval in shape, and have a distinct head, thorax and abdomen. The head is usually conical and pointed anteriorly and the mouth parts are hidden within the head. The legs are strong and bear powerful claws. Eyes are absent in the family *Hæmatopinidæ*, to which the common sucking lice of domestic animals belong. These are:

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* *Centr. f. Bact.*, 1, Orig., 121 (1/2): 40-49. 1931.

† *Zool. Anz.*, 56 (9/10): 231-233. 1923.

Hæmatopinus asini (Linné, 1755), the sucking louse of equines.

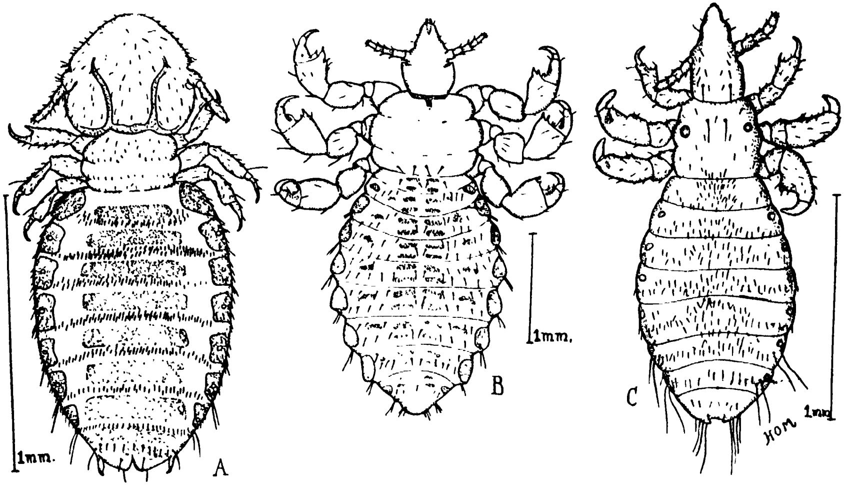

FIG. 245.—CATTLE LICE. (ORIGINAL.)
A, *Bovicola bovis ;* B, *Hæmatopinus eurysternus ;* C, *Linognathus vituli.*

H. suis (Linné, 1758), the very large louse of pigs.

H. eurysternus (Nitzsch, 1818), the "short-nosed" cattle louse, with a relatively short head and broad thorax and abdomen.

Linognathus ovillus (Neumann, 1907), the body louse or "blue

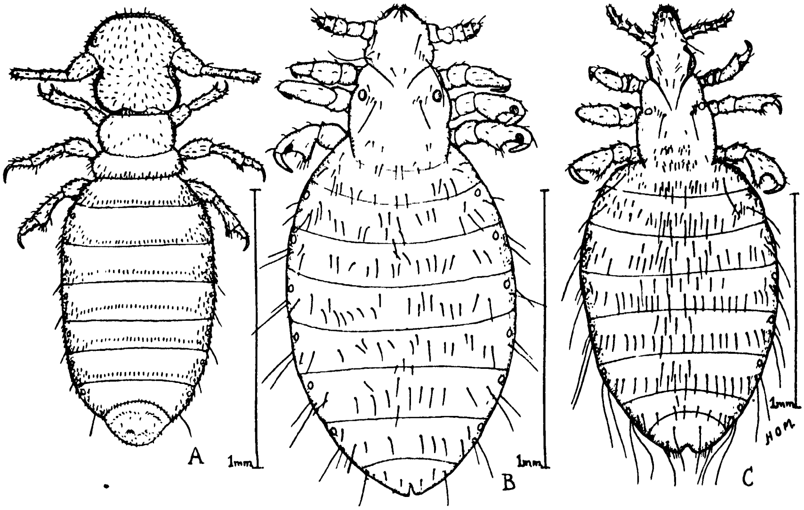

FIG. 246.—SHEEP LICE. (ORIGINAL.)
A. *Bovicola ovis ;* B, *Linognathus pedalis ;* C, *L. africanus*

louse" of sheep, occurs in New Zealand, Australia and Scotland. Its head is much longer than wide and also longer than the thorax.

L. vituli (Linné, 1758), the "long-nosed" cattle louse, which has an elongate head and body.

L. africanus Kellogg and Paine, 1911, the African "blue louse" of sheep.

L. pedalis (Osborn, 1896), the "foot louse" of sheep. The head is as wide as long and not longer than the thorax. This louse occurs on the legs and feet of the sheep where there is no wool.

L. stenopsis (Burmeister, 1838) on goats.

L. setosus (v. Olfers, 1816) (=*L. piliferus*) on dogs and foxes.

Solenopotes capillatus Enderlein, 1904, on cattle in Europe, U.S.A. and Australia.

Life-Cycle.—The eggs are yellowish in colour and have an operculum at the upper pole. They are attached to the hairs of the host and hatch in 7-12 days or even longer. The young louse passes through several ecdyses and reaches the adult stage in 2-3 weeks. The infection is spread by close contact of the hosts, since the lice do not leave their hosts spontaneously and cannot live long without them. In the case of horses, lice may be spread by curry-combs, brushes, blankets, saddles and harness transferred from one horse to another.

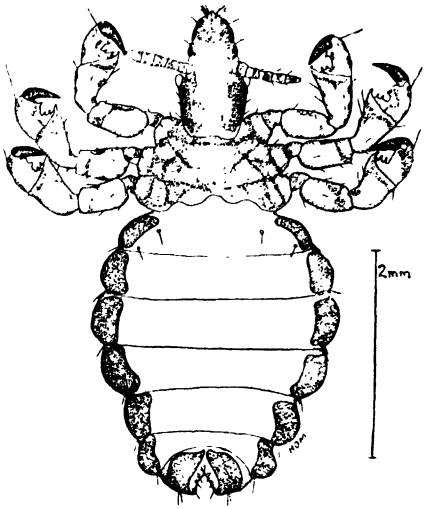

FIG. 247.—*Hæmatopinus suis*, FEMALE. (ORIGINAL.)

PEDICULOSIS IN DOMESTIC MAMMALS

Symptoms.—The biting as well as the sucking lice cause irritation, which results in scratching, rubbing and biting, and loss of condition on the part of the host. Scratching may produce wounds or bruises on the animal, while in sheep the wool is damaged and it is also soiled by the fæces of the lice. The coat becomes rough and shaggy, and in bad cases the hair becomes matted together. The skin turns dry and scaly, so that large scabs or crusts may form, resembling lesions of mange. The animals are restless; they do not feed well and their reduced condition may make them susceptible to other diseases. In the case of calves, lousiness leads to much licking, and since the hair is loose, hair-balls readily form in the stomach. The foot louse of sheep is found most frequently around the dew-claws, and severe infections may produce lameness.

Hæmatopinus suis may spread swine fever by passing from a dead pig to healthy ones.

Pediculosis is seen especially in winter in animals with a long winter coat and when they suffer from cold and insufficient feeding.

Diagnosis is easily made by finding the lice, especially when the animal is standing in the sunlight.

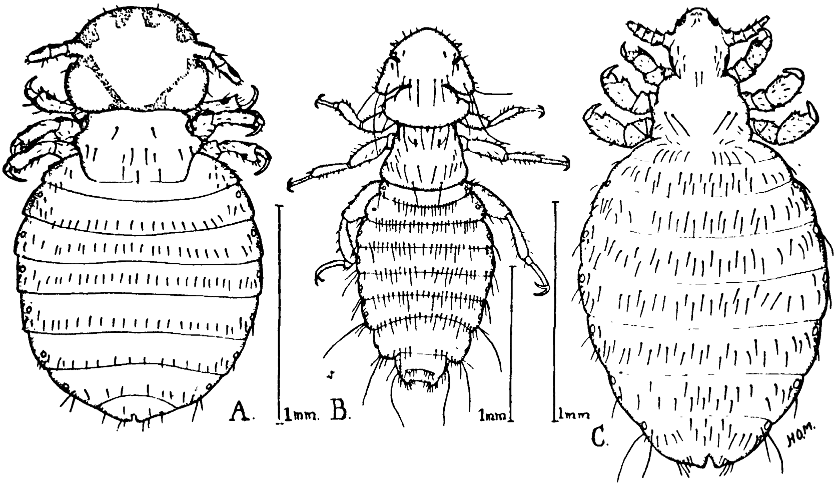

FIG. 248.—DOG LICE. (ORIGINAL.)
A, *Trichodectes canis* ; B, *Heterodoxus longitarsus* ; C, *Linognathus setosus.*

Treatment and Prophylaxis.—The great efficacy of DDT against lice should make the control of these parasites a relatively easy matter. It can be applied in the form of a powder—about 5 per cent. in a suitable vehicle such as talc—as a spray or perhaps as a dip.

Order SIPHONAPTERA

The fleas are wingless insects with laterally compressed bodies, about 1·5-4 mm. long. The chitinous covering is thick and dark brown. Compound eyes are absent, but some species have large or small simple eyes. The legs are long, strong and adapted to leaping. In some species, such as the dog flea, *Ctenocephalides canis* (Curtis, 1826), and the cat flea, *C. felis* (Bouche, 1835), there are a number of large spines on the head and the thorax—about 8 genal spines and 16 pronotal spines—known as "combs."

Life-Cycle.—The female flea lays up to 20 eggs. These are deposited in dust or dirt, or they may be laid on the host, but soon drop off, as they are not sticky. The eggs are about 0·5 mm. long, rounded at the poles and pearly white in colour. The rate of development varies greatly and depends also on the temperature and humidity. The larvæ may hatch in 2 days, or up to 16 days after the eggs have been laid. The egg-shell is broken by means of a chitinous spine, which is present on the head of the first larval instar. The larvæ are elongate, slender, maggot-like creatures, consisting of 14 segments, each of which bears a few long hairs. They are creamy yellow in colour and very active, hiding from light. They have masticatory mouth parts and feed on dry blood, fæces and other organic matter, but apparently require little food.

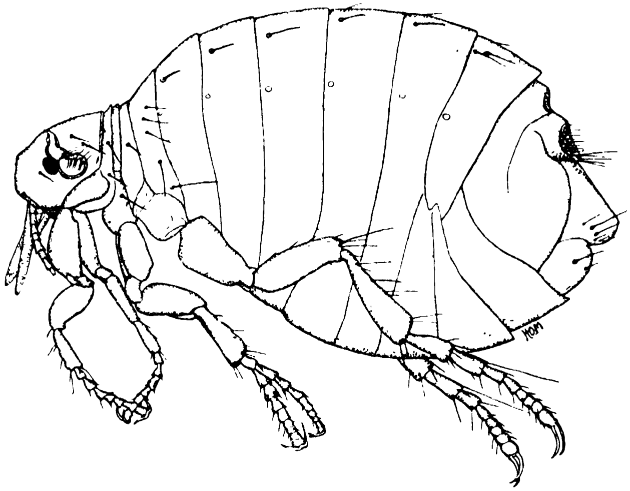

FIG. 249.—*Echidnophaga gallinacea.* (ORIGINAL.)

A moderate temperature and a high degree of humidity are favourable for development, which lasts 7-10 days or longer. The mature maggot is about 6 mm. long. It spins a cocoon which measures about 4 by 2 mm. In this the pupal stage is passed, lasting 10-17 days under average conditions, but a low temperature will cause the imago to stay in the cocoon.

Habits and Significance.—Fleas are much less permanent parasites than lice and frequently leave their hosts. Unfed fleas do not live long in dry surroundings, but may live several months in a humid environment if debris in which they can hide is present. Strickland kept specimens of the rat flea *Ceratophyllus fasciatus* without food for 17 months at a temperature of 15·5° C. and 70 per cent. humidity.

While lice are specific with respect to their hosts, fleas are not, and frequently attack species other than their normal host. They suck blood and produce very irritating bites. Fleas transmit the human plague bacillus, but they are not known to be vectors of important animal diseases. *Ctenocephalides canis*, *C. felis* and the human flea, *Pulex irritans*, are intermediate hosts of the tapeworm *Dipylidium caninum*. Cats, dogs, foxes, fowls, and more rarely other animals, may be much worried by fleas, so that they become restless, lose condition, and spoil their coat by biting and scratching. The poultry flea *Ceratophyllus gallinæ* is especially troublesome to laying and brooding hens.

The " stick-tight " flea of poultry, *Echidnophaga gallinacea*, which also attacks dogs, cats and other mammals and birds, attaches itself mainly to the comb, wattles and around the eyes of the birds. This flea does not jump away when disturbed and large numbers may be seen clustering together. Young birds are quickly killed by these fleas and even adult birds may succumb to heavy infections. The female of this flea burrows into the skin and lays its eggs in the ulcer produced. The eggs hatch there and the larvæ fall out to develop like the larvæ of other fleas, reaching the adult stage in about 4 weeks.

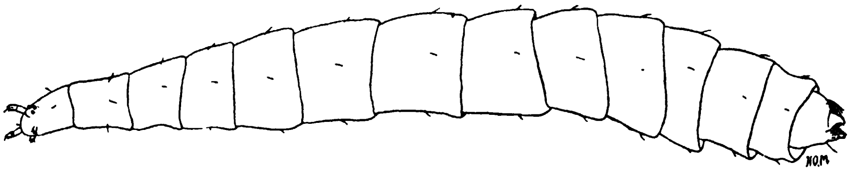

FIG. 250.—*Echidnophaga gallinacea*, LARVA. (ORIGINAL.)

Control.—DDT can be applied to animals in the same way as against lice, and floors of buildings, where the fleas breed, can be similarly treated. For treatment of animals, pyrethrins and rotenone are also effective.

CLASS ARACHNIDA

Order ACARIDA

Super-Family IXODOIDEA

This super-family contains the ticks and is subdivided into two families, the *Argasidæ*, which includes the fowl ticks and tampans, and the *Ixodidæ*, or true ticks.

Family ARGASIDÆ

The integument is leather-like, frequently mammillated, and there is no dorsal shield. In the nymph and imago the capitulum and mouth parts are situated anteriorly on the ventral surface and are not visible from the dorsal aspect. Eyes are absent, or there may be two pairs situated laterally in the supra-coxal folds. One pair of spiracles situated postero-laterally to the third coxæ. Sexual dimorphism not marked.

Genus **Argas** Latreille

A. persicus (Oken, 1818), the "fowl tick," is a common parasite in many warm and temperate climates, attacking fowls, turkeys, pigeons, ducks, geese, canaries, ostriches and certain wild birds, and it may also bite man. The imago measures 4-10 by 2·5-6 mm. and is oval in shape, narrower anteriorly than posteriorly. The edges of the body are sharp. The engorged tick has a slaty-blue colour, while the starved animal is yellowish-brown with the dark intestine showing through. As in other *Argasidæ* there is little difference between the males and the females; the sexes can be distinguished only by the shape of the genital opening, which is situated anteriorly on the ventral surface and is larger in the female than in the male.

Life-Cycle and Habits.—The eggs are laid in cracks and crevices of the fowl-house and under the bark of trees. They are small, spherical, brown in colour and are laid in batches of 20-100. The larvæ hatch after 3 weeks or more; they have six relatively long legs and roughly circular bodies, which become spherical after engorging. The larvæ attach themselves to the host, frequently under the wings, and engorge in about 5 days, rarely up to 10 days. Then they drop off and hide away, to moult after about 7 days. There are two nymphal stages, each of which lasts about 2 weeks and engorges once during this time. The nymphs and the adults hide away in sheltered spots and attack their hosts at night, feeding for about 2 hours. The adults feed once a month, more or less, and the females lay a batch of eggs after each meal. The larvæ can live without food for about 3 months. The nymphs and the adults survive starving for about 5 years.

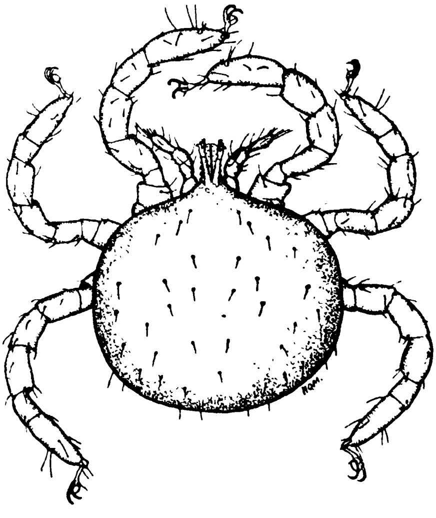

FIG. 252.—*Argus persicus*, LARVA. (ORIGINAL.)

Significance.—The fowl tick worries the birds at night so that they sleep restlessly, and in heavy infections anæmia results from the loss of blood. Egg laying decreases or may stop completely. The parasite is also the vector of fowl spirochætosis, a fatal disease caused by *Spirochæta anserina*, and the poultry piroplasm, *Ægyptionella pullorum*. The spirochæte is passed through the egg to the offspring of an infected female tick, so that it can be eradicated only with the ticks.

Diagnosis.—The parasites will be found in cracks of the woodwork or the walls of the fowl-house.

Control.—Possibly preparations of DDT may be used against the fowl tick. On the birds, against the larvæ, it will probably be quite effective. The classical procedure against fowl ticks in buildings is as follows: The birds have to be removed from their run and houses and placed in wooden crates, which afford ample hiding-places for the parasites. The larvæ on the birds will drop off within 10 days and the fowls can then be returned to their quarters, which have meanwhile been cleaned. All birds subsequently introduced should be treated in the same way. The crates can be cleaned by scalding with boiling water or spraying with paraffin emulsion, or they can be burnt. The buildings are best burnt down if they are not well made. Otherwise all rubbish, loose wood and bark of trees should be removed and burnt. If the buildings are composed of metal they can easily be sterilised by means of a painter's blow-lamp. Wooden structures should be thoroughly sprayed with paraffin emulsion* at a good pressure and, after having dried, all cracks are closed by painting with hot tar and the walls are whitewashed. Unless the work is done well the ticks may not be exterminated and it may be necessary to spray the building twice with an interval of about 10 days. The stems and lower branches of trees nearby should also be sprayed.

In order to protect the birds if reinfection is liable to occur, the perches may be suspended from the roof by means of wires which pass through small cups of oil to prevent the ticks from climbing down along the wires, but it is preferable to construct detachable perches which can be removed at intervals and cleaned by scalding.

Genus **Otobius** Banks

O. megnini (Duges, 1883), the "spinose ear tick," was introduced from America into Africa. Its larval and nymphal stages are parasites in the ears of sheep, goats, and cattle, but are sometimes also found in equines, dogs, cats, ostriches and man. The engorged larvæ are reddish-brown and almost spherical. The nymphæ are widest at the middle and their skin is mammillated and bears numerous spine-like processes; the body colour is bluish-grey, while the legs, mouth parts and spines are pale yellow. The adults, which are not parasitic, have a constriction at the middle, giving the body a fiddle shape.

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* Boil 0·5 kg. soap in 10 litres of water to dissolve; remove from the fire and add 10 litres of paraffin, mixing well until a creamy emulsion is obtained. It is advantageous to add 150 c.c. of 40 per cent. nicotine sulphate. For spraying, dilute one part of this emulsion with 6¼ volumes of water.

Life-Cycle and Habits.—The eggs are laid in sheltered spots such as cracks of poles, under food-boxes or stones, or in crevices of walls. The infection is therefore mainly associated with sheds, yards and kraals, and is hardly ever seen in ranch animals that remain in the open pasture. The larvæ hatch in 3-8 weeks and may live without food for 2-4 months. If they find a suitable host, they attach themselves in the ears and engorge in 5-10 days. The larvæ suck mainly lymph, so that engorged larvæ are usually white in colour. Their shape is almost spherical and the legs are relatively small. They moult in the ears, and the nymphs, having also engorged, leave the host after a total period of about 36 days or sometimes longer. The nymph hides away and after 7-31 days it moults, to become an imago. The adults do not feed, but the females may live up to 2 years and lay several batches of eggs.

Pathogenesis and Symptoms.—The parasites suck blood and cause marked irritation, which results in an inflammation of varying degree. Secondary bacterial infection causes the process to become purulent and it may extend inwards with serious results. In heavy infections death may occur. The infected animals appear dull and worried; they do not feed well, lose condition, and dogs especially shake the head and scratch the ears. A waxy or oily exudate from the ear is usually present.

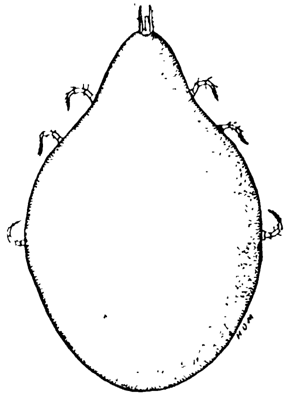
FIG. 254.—*Otobius megnini*, ENGORGED LARVA. (AFTER MÖNNIG.)

Diagnosis.—The waxy exudate is removed and the ear probed by means of a suitable piece of wire with a small loop at the end, which will assist in dislodging and extracting a few parasites if they cannot be seen by direct inspection.

Treatment and Prophylaxis.—Suitable DDT preparations will probably be quite effective against the stages occurring in the ears of animals. Large animals can also be treated with a mixture of two parts good quality Stockholm tar, two parts cotton-seed oil, and one part turpentine. The excessive earwax is removed and about 4-12 c.c. of the mixture, warmed if necessary, are injected deeply into the ear by means of a metal syringe. The ear should be manipulated during the injection so as to get the mixture in as far as possible. Too large quantities should not be given, since the skin may be blistered if some of the mixture runs out over the face. The treatment should be repeated once a month until the infection decreases and then at longer intervals.

Infected sheds or kraals have to remain unused for several years in order to starve out the ticks. Where the tick is troublesome, kraals are best made with wire and iron standards or well-tarred poles.

Genus **Ornithodoros** Koch

O. moubata Murray, 1877, the eyeless tampan, lives in native huts and in the sand under trees where animals and human beings frequently seek shelter. The female lays batches of about 100 eggs in the sand. The larvæ do not hatch, but moult in the egg so that the nymphs hatch out. Several nymphal instars are passed through and the nymphs, like the adults, attack their hosts for short periods only to feed. This tampan sucks blood on man and various domestic and wild animals, including birds and even tortoises. In certain localities, for instance in South-west Africa, this parasite causes much trouble by feeding on sheep at their resting-places in the pasture and it is very difficult to combat under such conditions. African relapsing fever of man, caused by *Spirochæta duttoni*, is transmitted by this tampan. *O. hermsi* and *O. moubata* transmit American Q fever (*Rickettsia diaporica*).

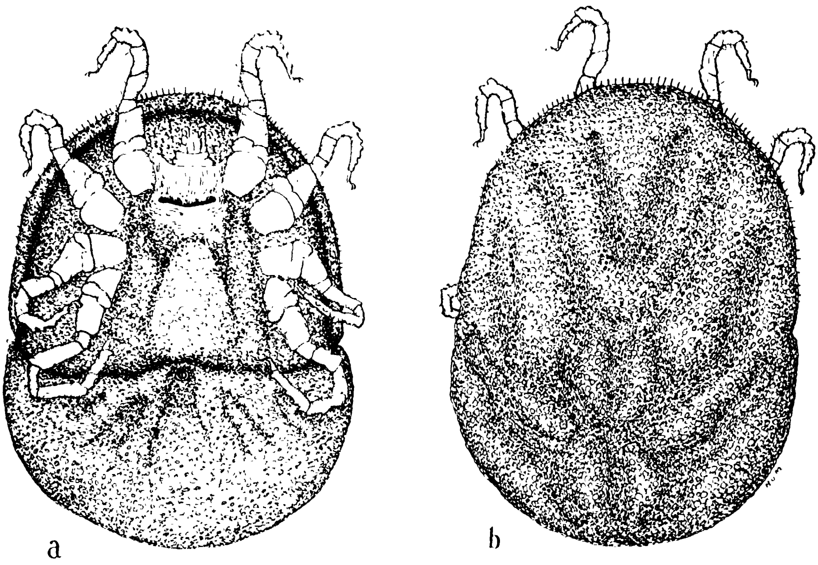

FIG. 255.—*Ornithodoros moubata*, FEMALE. (ORIGINAL.)
a, Ventral; *b*, dorsal view.

O. savignyi Audouin, 1827, is a tampan which possesses eyes and has habits similar to those of *A. moubata*. In this case the larvæ hatch from the eggs, but do not feed.

PLATE XV

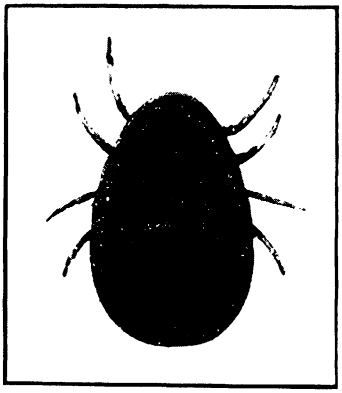

FIG. 251.—*Argas persicus*, DORSAL VIEW.

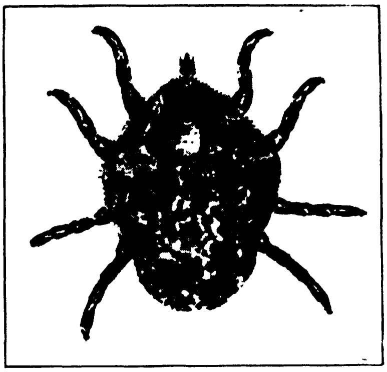

FIG. 253.—*Otobius megnini*. NYMPH.

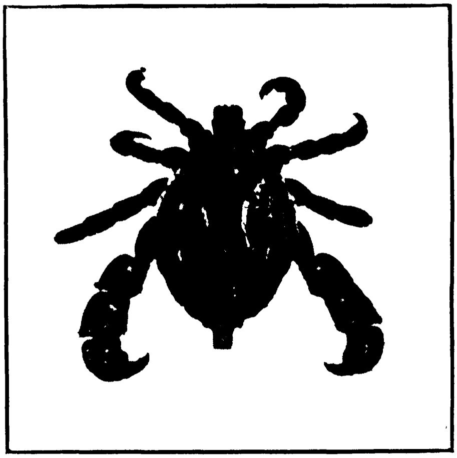

FIG. 257.—*Margaropus winthemi*, MALE.

[*To face page* 362.

Family IXODIDÆ

There is a hard, chitinous shield or scutum which extends over the whole dorsal surface of the male and covers only a small portion behind the head in the larva, nymph and female. The mouth parts are anterior and well visible from the dorsal aspect. Eyes when present consist of one pair situated on the lateral margin of the scutum. The imago has one pair of spiracles situated postero-laterally to the fourth coxæ.

The basis capituli or capitulum, which is inserted into the body anteriorly and carries the mouth parts and palps, shows two dorsal porose areas in the female. The scutum has bilateral cervical and lateral grooves, varying in depth and length in different species. The body of the female may have a pair of lateral " marginal grooves " behind the scutum, while postero-lateral and median grooves are usually present on the dorsum in both sexes. The posterior border of the body is frequently notched, forming the " festoons," which are generally 11 in number. The genital opening is a transverse slit situated in the anterior half of the ventral surface. The anus opens in the posterior half. Ventral plates, which are of great value in the identification of ticks, may be present in the male.

Bionomics.—The *Ixodidæ* lay their eggs in sheltered spots: under stones and clods of soil or in crevices of walls and cracks of wood near the ground. The eggs are small, spherical, yellowish-brown to dark brown in colour and are laid in large masses. The female lays all her eggs in one batch, numbering up to 18,000 in some species, and then dies. The whole process of development to the adult stage is greatly influenced by the prevailing temperature, cold weather causing marked prolongation of the different stages, especially hatching of the eggs and the pre-oviposition period of the engorged female.

The newly hatched larvæ or " seed ticks " climb on to grass and shrubs in order to attach themselves to a passing host. After having engorged, the larva moults and becomes a nymph. The integument of the latter requires a few days to harden, and then the nymph engorges and moults, to become an imago. After hardening of the integument, and often also after copulation, which may take place on the ground or, more usually, on the host, the female engorges, drops off and seeks a sheltered spot to lay. The males remain much longer on the host than the females, in some cases 4 months or even longer, and consequently they accumulate on the host. Although it is not definitely known whether the males of all species feed on the host, many of them certainly do so for a few days and then go in search of females. If no males are present on the host, the females may remain attached for much longer periods than under normal conditions.

According to the number of hosts they require during their life-cycle, ticks can be classed in three groups:

1. *One-Host Ticks.*—All three instars engorge on the same animal, the two ecdyses also taking place on the host—*e.g. Boophilus decoloratus, B. annulatus.*

2. *Two-Host Ticks.*—The larva engorges and moults on the host and the nymph drops off after also having engorged; it moults on the ground and the imago seeks a new host—*e.g. Rhipicephalus evertsi, R. bursa.*

3. *Three-Host Ticks.*—The majority of ticks require a different host for every instar; they drop off each time after having engorged and moult on the ground.

Each species of tick is adapted to certain ranges of temperature and moisture, some occurring only in warm regions with a fair degree of humidity, while others are winter ticks and most active in a dry climate. They suck blood and sometimes lymph and are in general not very specific with regard to hosts, although some species, or certain instars of a species, show a particular preference for certain host species, or there may be a definite adaptation to certain hosts. When a tick attaches itself to feed, it buries its mouth parts deeply into the tissues of the host and remains attached until it is engorged. If it should be detached before engorgement is complete, it will rarely feed again in the same instar.

The following key to the genera of *Ixodidæ* is adapted from Bedford:*

1. Anal grooves surrounding the anus anteriorly . . . . *Ixodes.*
   Anal grooves surrounding the anus posteriorly (in *Boophilus* and *Margaropus* the anal groove is faint or obsolete) . . . 2.
2. Hypostome and palpi short . . . . 3.
   Hypostome and palpi long . . . . 8.
3. Eyes absent . . . . *Hæmaphysalis.*
   Eyes present . . . . 4.
4. Festoons present . . . . 5.
   Festoons absent . . . . 7.
5. Males with coxæ IV much larger than coxæ I to III; no plates or shields on ventral surface of male . . . . 6.
   Males with coxæ IV not larger than coxæ I to III, a pair of adanal shields and usually a pair of accessory adanal shields on ventral surface of the male. Species usually inornate; basis capituli generally hexagonal dorsally . . . . . *Rhipicephalus.*
6. Species ornate; basis capituli rectangular dorsally . *Dermacentor.*
   Species inornate; basis capituli hexagonal dorsally with prominent lateral angles. Coxæ IV of male with two long spines . . . *Rhipicentor.*
7. Inornate; coxæ I with a small spine. Male with median plate projecting backwards on either side of the anus and with a caudal protrusion when engorged. Fourth pair of legs of male dilated. *Margaropus.*

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* *18th Rep. Dir. Vet. Serv. and Anim. Ind., Union of South Africa,* pp. 221-523, 1932.

Inornate; coxæ I bifid. Male with a pair of adanal and accessory shields and a caudal protrusion. Fourth pair of legs normal. *Boophilus.*

8. Eyes present . . . . 9.
Eyes absent or rudimentary. Species occurring almost exclusively on reptilia . . . . *Aponomma.*

9. Festoons absent or present. Males with a pair of adanal shields and two posterior abdominal protrusions. Accessory adanal shields absent or present . . . . *Hyalomma.*
Species usually ornate; festoons present. Male without adanal shields, but small plaques may be present on the venter near the festoons . . . . *Amblyomma.*

Genus **Ixodes** Latreille, 1795*

The anal groove surrounds the anus anteriorly. Palpi long. Inornate. Eyes and festoons absent. Ventral surface of male armed with pregenital, median, anal, epimeral, and adanal shields, the latter two being paired. Stigmatic plates oval in male, circular in female.

I. ricinus (Linné, 1746), the "castor-bean tick," is common in Europe, and occurs also in some other countries. It is frequently found on dogs, but also occurs on other domestic and wild mammals, while nymphs and larvæ have been recorded from lizards and birds. The following data on the life-cycle of the parasite are compiled from various authors:

Pre-oviposition period	7-22 days.
Oviposition lasts	About 30 days.
Eggs hatch (depending on temperature)	2-36 weeks.
Larvæ engorge	2-6 days.
Larvæ moult (depending on temperature)	4-51 weeks.
Nymphs engorge	3-7 days.
Nymphs moult (depending on temperature)	8-28 weeks.
Females engorge	5-14 days.
Unfed larvæ survive	13-19 months.
Unfed nymphs survive	24 months.
Unfed adults survive	21-27 months, extreme 31 months.

The larvæ and nymphs are usually attached to the ears, eyelids and other parts of the head, rarely on the body. The adults attach to the flanks, legs, under the tail and, in dogs, often on the head and neck.

I. ricinus transmits redwater of cattle caused by *Babesia bovis*, *Anaplasma marginale*, the virus of louping ill and the virus of "tick-borne fever" in sheep. The piroplasm passes through the egg of the tick.

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* Nuttall and Warburton, *Ticks, a Monograph of the Ixodoidea*, Pt. II. Cambridge University Press, 1911.

I. pilosus Koch, 1844, the " paralysis tick " or " russet tick," occurs in many parts of South Africa on domestic and some wild mammals.

Lounsbury gives the following data on the life-cycle:

Pre-oviposition and incubation period (summer)	43-93 days.
Pre-oviposition and incubation period (winter)	222-309 days.
Larvæ engorge	2¾ days or longer.
Larvæ moult (summer)	27 days.
Nymphs engorge	4 days.
Nymphs moult (autumn)	52 days.
Females engorge (males present)	5-6 days.

The ticks are particularly frequent in the vicinity of low hills with red ironstone and are most prevalent from autumn to early spring. The larvæ and nymphs engorge on small rodents like hares and mice. The adults attach to those parts of the body that are not covered by wool or long hair, such as the legs, flanks, and sometimes the head, rarely on the abdomen of non-wooled sheep.

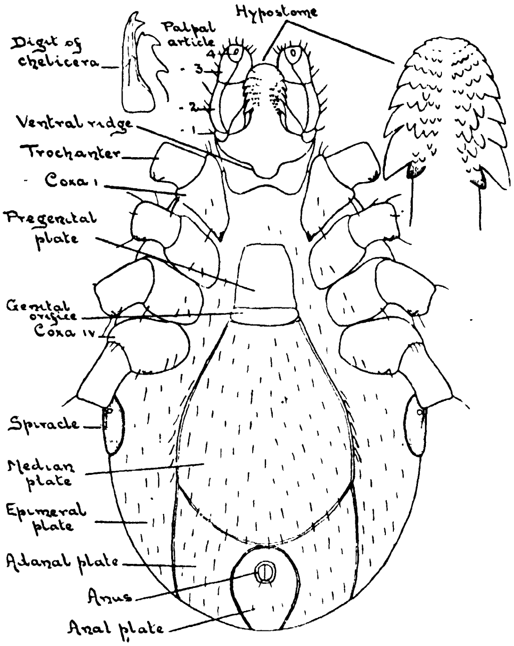

FIG. 256.—*Ixodes pilosus*, VENTRAL SURFACE OF MALE. (AFTER BEDFORD.)

This species causes paralysis in sheep and goats, rarely in cattle and antelopes. The paralysis appears to be caused by the toxic action of a substance injected by the tick into the skin. It has been noted that the salivary glands become very large in ticks which cause paralysis. According to Gregson (1937), who investigated paralysis caused by *Dermacentor andersoni*, the tick appears to inject this substance to produce a hyperæmia where it feeds, and he has observed that those ticks which feed rapidly—*i.e.* those which are able to produce a good hyperæmia by injecting a strong toxin—are the most dangerous. A single tick may produce the condition and only a small percentage of individuals are able to do so. The affected animal shows a rapidly progressing paralysis of the limbs, and there may be a nasal catarrh but no fever. In severe cases the neck is twisted to one side. For treatment it is only necessary to remove the ticks and to attend to torticollis, if present. For prophylaxis the animals should not be grazed near hills, and sheep are made to walk every 2 weeks through a shallow dipping-tank 26 inches deep, 30 inches wide and 36 feet long, containing a 0·2 per cent. solution of sodium arsenite (80 per cent.), standing 18 inches deep in the tank.

I. rubicundus is also a paralysis tick which occurs in the dry regions of South Africa.

I. holocyclus, the paralysis tick of Australia,* is prevalent along the east coast of New South Wales and Queensland. It occurs on man, dogs, cats, other domestic animals and the bandicoot (*Perameles*), which appears to be its most important host. The tick is very susceptible to variations in temperature and humidity. The female lays 2,000-3,000 eggs and each instar engorges normally in 5-6 days.

The paralysis is caused by adult females, of which one may suffice, and in rare cases also by large numbers of nymphæ. Fatal paralysis has been produced in mice by injecting the salivary glands of engorged ticks. The paralysis is mainly of importance in dogs. It usually begins towards the end of the fourth or the beginning of the fifth day after attachment of the ticks. If there are many ticks on a small pup, symptoms may appear at the beginning of the fourth day. There is a rapidly progressing motor paralysis affecting first the hind-quarters and then the forelegs, the muscles of the head and neck and the respiratory muscles. Vomition may be marked. Initially there may be a fever, but soon the temperature drops to subnormal. Death appears to be due to respiratory paralysis.

Recovered animals are immune and dogs can be hyperimmunised by frequently allowing ticks to engorge on them. The serum of such dogs has a highly curative value and is used for that purpose. Weekly applications of derris powder or a 1 per cent. soapy cold water infusion of derris is a good prophylactic if it is thoroughly applied to the whole body, but even then ticks may attach to the eyelids or bare parts.

I. scapularis transmits anaplasmosis of cattle in the United States.

Genus **Boophilus** Curtice, 1891

Anal groove obsolete in female, faint in male and surrounding the anus posteriorly. Inornate. Eyes present. Festoons absent. Palps and hypostome short; palps with prominent transverse ridges. Coxa I bifid. Spiracles circular or oval. Males small, provided with adanal or accessory shields and a caudal process; fourth pair of legs of ordinary size.

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* Ross, *Journ. Counc. Sc. Ind. Res.*, 8 (1): 8-13. 1935.

B. annulatus (Say, 1821), the "North American cattle tick," is native to North America. It occurs usually on domestic and wild ungulates, but has also been found on other animals and man.

Various authors* give the following data on the life-cycle:

Pre-oviposition period	3-25 days.
Oviposition lasts	14-59 days.
Larvæ hatch	23-159 days.
Parasitic period on host	15-55 days.

Unfed larvæ survive up to 8 months.

This species, like other members of the genus, is therefore a one-host tick. It transmits Texas fever (*Babesia bigemina*) of cattle, the infection passing through the egg of the tick.

The ticks are relatively easily killed by arsenical dips and can be exterminated by regular dipping at intervals of 14 days. If all animals that carry the tick are treated, any given area should be cleaned of this tick in about 10 months. In 1891 a campaign of extermination by systematic dipping against this tick was started in the United States, working southwards from the northern limits of distribution of the parasite, with the result that the greater part of the infected area has now been cleaned.

B. decoloratus (Koch, 1844), the "blue tick," is common in many parts of South Africa. It parasitises chiefly on cattle and equines, but is also found on sheep and goats, wild ungulates and dogs. The engorged females have a slaty-blue colour and pale yellow legs.

The female lays up to 2,500 eggs, which hatch in 3-6 weeks under favourable conditions. This is a one-host tick, requiring 22 days (summer) to 38 days (winter) for its development on the host. Unfed larvæ survive up to 7 months.

This species transmits redwater (*B. bigemina*) and gall-sickness (*Anaplasma marginale*) of cattle, spirochætosis (*Spirochæta theileri*) of cattle, horses, goats and sheep, and *B. trautmanni* of pigs in East Africa. In all cases the infection passes through the eggs of the tick.

Control can be effected by dipping at intervals of 14-21 days, and regular dipping of all animals for about 9 months should exterminate the tick.

B. microplus (Canestrini, 1887) (syn. *B. australis*, Fuller, 1899) occurs in Australia, South America, Asia and South Africa, and is a transmitter of *B. bigemina*, *B. bovis* and *A. marginale.*

B. calcaratus (Birula, 1895) transmits *B. bigemina* and perhaps also *Theileria annulata* of cattle in Transcaucasia.

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* See Bishopp, *Dissert. Ohio State Univ. No.* 9, 1932. Graybill and Lewallen, *U.S. Dept. Agric., Bull. No.* 152, 1912.

Genus **Margaropus** Karsch, 1879

This genus, of which *Boophilus* is regarded as a synonym by some authors, differs from the latter genus in that the males are large, their fourth pair of legs is markedly thickened, and they have a median ventral plate which is prolonged into two spines projecting on either side of the anus; coxa I has a small posterior spine.

M. winthemi Karsch, 1879, the "Argentine tick," is a native of South America which has also been introduced into South Africa. It is a parasite of horses and sometimes occurs also on cattle. The engorged female resembles that of *B. decoloratus*, but has dark bands at the joints of the legs.

This is a one-host tick which is especially prevalent in winter. It is not known to transmit any disease.

Genus **Hyalomma** Koch, 1844

Inornate, sometimes ornate. Eyes present. Festoons present or absent. Hypostome and palps long. Male with a pair of adanal shields and sometimes accessory adanal shields; frequently a pair of chitinous protrusions behind the adanal shields. Spiracles comma-shaped in male, triangular in female.

H. ægyptium (Linnæus, 1758), the "bont-leg tick," has two varieties: *H. ægyptium ægyptium*, which occurs in Africa, Southern Europe and Asia; and *H. ægyptium impressum* in Africa. The adults are parasitic on cattle, sheep, goats, equines, dogs, cats, wild mammals and sometimes birds; the latter variety has been found on ostriches. The larvæ and nymphæ usually feed on rodents such as hares, and on birds, including poultry. In the adults the shield is dark brown with numerous punctations; the eyes are large and black; coxæ I with two large spurs; the legs are reddish-brown and ringed with white on the distal parts of the joints, giving the tick a characteristic appearance. As a rule this is a two-host tick, the larvæ and nymphæ engorging on the same host, but the larvæ may drop off. The female lays 10,000-15,000 eggs.

Pre-oviposition period	4-12 days.
Oviposition lasts	37-59 days.
Larvæ hatch	34-66 days.
Larvæ engorge	5-7 days.
Larvæ moult	2-15 days.
Nymphæ engorge	7-10 days.
Nymphæ moult	14-95 days.
Larvæ and nymphæ on host	13-45 days.
Females engorge	5-6 days.
Unfed larvæ survive	12 months.
Unfed nymphæ survive	3 months.
Unfed adults survive	14 months or longer.

The tick is very hardy and consequently has a wide range of distribution, occurring in warm and cold regions. The adults attach mainly in the perineal and genital regions of their host and may produce bad wounds. Sheep are often bitten on the coronary bands of the feet or between the claws, so that they go lame. This tick has been incriminated as a vector of exanthematic fever (*Rickettsia conori*), *H. ægyptium impressum* was found to transmit *Theileria parva* and *T. dispar*, and a *Hyalomma* species, probably *H. ægyptium*, transmits *Rickettsia bovis*.

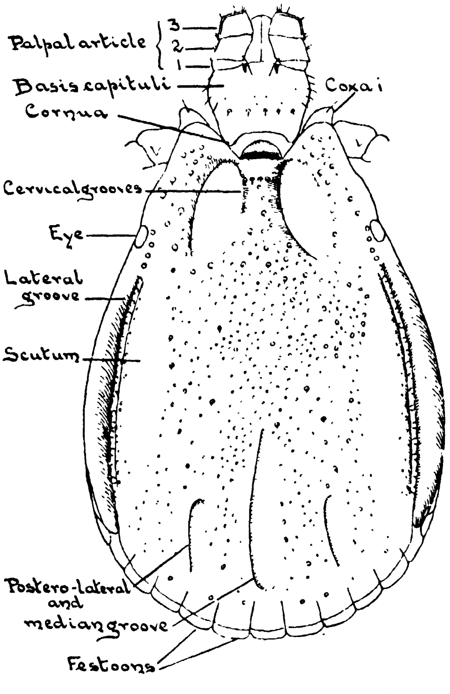

FIG. 258.—*Rhipicephalus appendiculatus*, DORSAL VIEW OF MALE. (AFTER BEDFORD.)

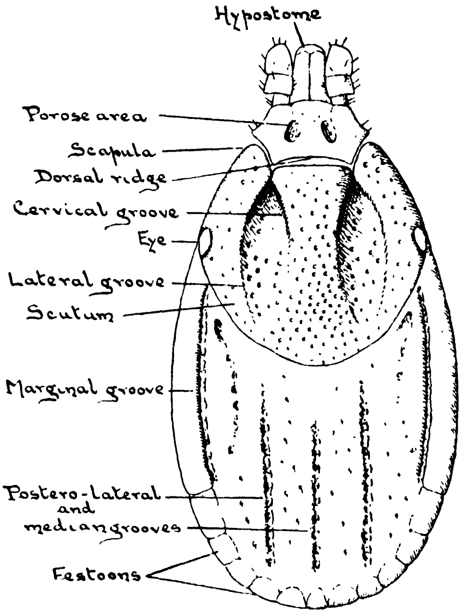

FIG. 259. — *Rhipicephalus appendiculatus*, DORSAL VIEW OF FEMALE. (AFTER BEDFORD.)

H. mauritanicum Senevet, 1922, transmits *Theileria dispar* of cattle in North Africa.

H. detritum, H. savignyi, H. dromedarii and **H. marginatum** transmit *Theileria annulata*.

H. anatolicum, H. dromedarii, and **H. marginatum** transmit *Babesia caballi*, while **H. anatolicum** also transmits *Nuttallia equi*.

Genus **Rhipicephalus** Koch, 1844

Usually inornate. Eyes and festoons present. Hypostome and palpi short. Coxæ I with two strong spurs. Males with adanal and usually also accessory adanal shields; frequently with a caudal prolongation when engorged. Spiracles comma-shaped, short in the female and long in the male. This genus contains a large number of species which are difficult to differentiate and are important vectors of infectious diseases.

R. appendiculatus Neumann, 1901, the "brown tick," is widely distributed in Africa south of the equator. It is parasitic on cattle, equines, sheep, goats, wild antelopes, and has also been found on the dog and wild rodents.

This is a three-host tick. The female lays about 3,000-5,000 eggs.

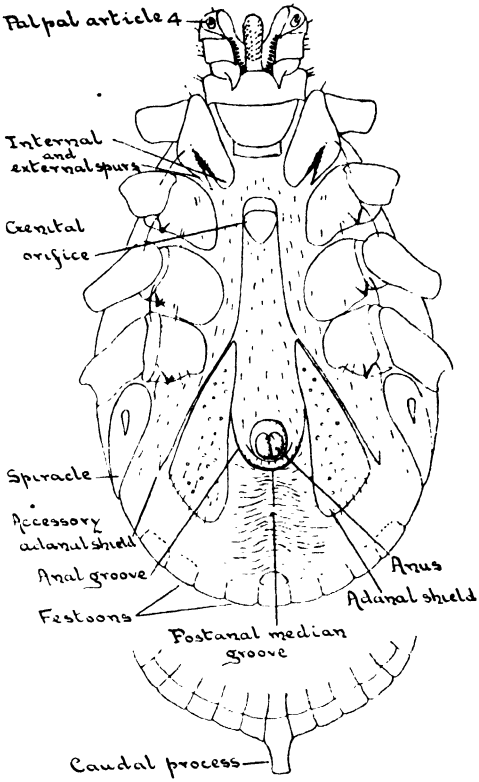

Fig. 260.—*Rhipicephalus appendiculatus*, Ventral View of Male. (After Bedford.)

Pre-oviposition period	5-40 days.
Eggs hatch (summer)	28 days.
Eggs hatch (winter)	3 months.
Larvæ engorge	3-7 days.
Larvæ moult	10-49 days.
Nymphs engorge	3-7 days.
Nymphs moult	10-61 days.
Females engorge	4-10 days.
Unfed larvæ survive	7 months.
Unfed nymphs survive	6½ months.
Unfed adults survive	14 months, sometimes longer and exceptionally over 2 years.

This species occurs in a relatively warm climate only. It attaches most frequently under the tail and in the ears, but may also be found on other parts of the body. This tick is the chief vector of East Coast fever (*Theileria parva*) of cattle. It also transmits *Hepatozoon canis* and exanthematic fever of dogs, *Theileria mutans* and *Babesia bigemina* of cattle, and the viruses of Nairobi sheep disease and louping-ill. In none of these cases except *B. bigemina* does the infection pass through the egg of the tick.

R. capensis and *R. simus*, both three-host ticks, transmit East Coast fever (*T. parva*), and the last-mentioned also transmits *Anaplasma marginale.*

R. sanguineus (Latreille, 1806), the "brown dog tick," has a more or less cosmopolitan distribution. It is mainly parasitic on dogs and is frequently associated with kennels, but has also been found on various other animals.

This is a three-host tick. The female lays 2,000-3,900 eggs.

Eggs hatch	17-30 days or longer.
Larvæ engorge	2-4 (-6) days.
Larvæ moult	5-23 days.
Nymphs engorge	4-9 days.
Nymphs moult	11-73 days.
Females engorge	6-21 days.
Unfed larvæ survive	Up to 8½ months.
Unfed nymphs survive	Up to 6 months.
Unfed adults survive	Up to 19 months.

This tick transmits canine piroplasmosis or biliary fever (*Babesia canis*) —the infection passing through the egg of the tick—*Rickettsia canis*, Rocky Mountain spotted fever, exanthematic fever (*Rickettsia conori*), Q fever (*R. burneti*), and gall sickness (*Anaplasma marginale*) of cattle. It has been incriminated as a vector of *B. bigemina*, *N. equi* and *Theileria annulata.*

R. evertsi Neumann, 1897, the "red tick," is common in Africa south of the equator and parasitises on many species of domestic and wild mammals. This species can be distinguished from other members of the genus by its red legs; the shield is black and densely pitted and in the male it leaves a red margin of the body uncovered. This is a two-host tick; the larval and nymphal stages engorge on the same host.

Pre-oviposition period	6-24 days.
Eggs hatch	4-10 weeks.
Larvæ and nymphs on host	10-15 days.
Nymphs moult	42-56 days.
Females engorge	6-10 days.
Unfed larvæ survive	7 months.
Unfed adults survive	14 months.

The larvæ and nymphs are usually found in the ears or the inguinal region, the adults mainly under the tail.

This species transmits East Coast fever (*T. parva*), redwater (*B. bigemina*) and *T. mutans* of cattle, *Spirochæta theileri* to various animals, and biliary fever (*Nutallia equi*) of horses. In the case of redwater and spirochætosis, the infections pass through the egg of the tick.

R. bursa Canestrini and Fanzago, 1878, is widely distributed in Southern Europe, Africa and elsewhere, and transmits ovine piroplasmosis (*Babesia ovis*), *Rickettsia ovina*, *B. bigemina*, *B. motasi*, *Theileria ovis*, *A. marginale* and equine piroplasmosis (*N. equi*).

Genus **Hæmaphysalis** Koch, 1844

Inornate. Eyes absent. Festoons present. Palps usually short and conical, the second articles having conspicuous lateral projections. The trochanter of the first pair of legs bears a dorsal process. Spiracles in female ovoid or comma-shaped; in males ovoid. Ventral surface of male without chitinous plates. Species usually of small size.

H. leachi (Audouin, 1826), the "dog tick," occurs in Africa, Asia and Australia. It is mainly parasitic on domestic and wild carnivora, frequently also on small rodents and rarely on cattle. This is a three-host tick. The female lays about 5,000 eggs.

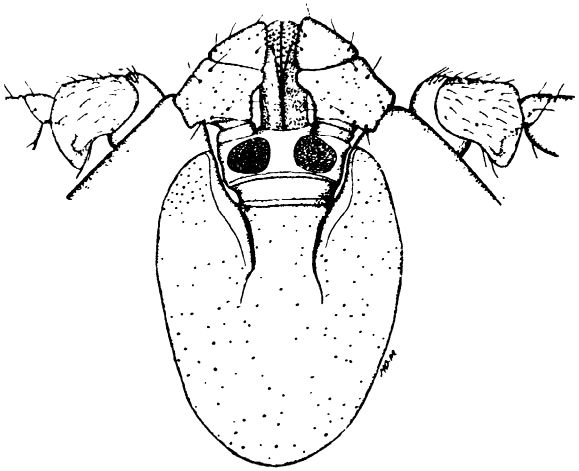

FIG. 261.—*Hæmaphysalis leachi*, ANTERIOR END OF FEMALE, DORSAL VIEW. (ORIGINAL.)

Pre-oviposition period	3-7 days.
Eggs hatch (20° C.)	26-37 days.
Larvæ engorge	2-7 days.
Larvæ moult	about 30 days.
Nymphs engorge	2-7 days.
Nymphs moult	10-16 days.
Females engorge	8-16 days.
Unfed larvæ survive	6 months or longer.
Unfed nymphs survive	2 months or longer.
Unfed adults survive	7 months or longer.

The tick lives on the head and body of its host and transmits canine piroplasmosis (*B. canis*), the infection passing from one imago to the next, and exanthematic fever (*Rickettsia conori*).

H. cinnabarina punctata Canestrini and Fanzago, 1878, occurs in Europe, Japan and North Africa. While the adults parasitise cattle and other mammals, the larvæ and nymphs are also found on reptiles.

Stockmann and Nuttall give the following data on the life-cycle:

The female lays 3,000-5,000 eggs.

Pre-oviposition period	10 days to 7 months.
Oviposition lasts	24-29 days.
Larvæ hatch (14° C.)	38-82 days.
Larvæ engorge	4-19 days.
Larvæ moult	14-238 days (winter).
Nymphs engorge	4-33 days.
Nymphs moult	7-295 days (winter).
Females engorge	6-30 days.
Unfed larvæ survive	10 months.
Unfed nymphs survive	$8\frac{1}{2}$ months.
Unfed adults survive	$8\frac{1}{2}$ months.

This species transmits redwater (*B. bigemina*) and *A. marginale* of cattle and causes paralysis of sheep and cattle.

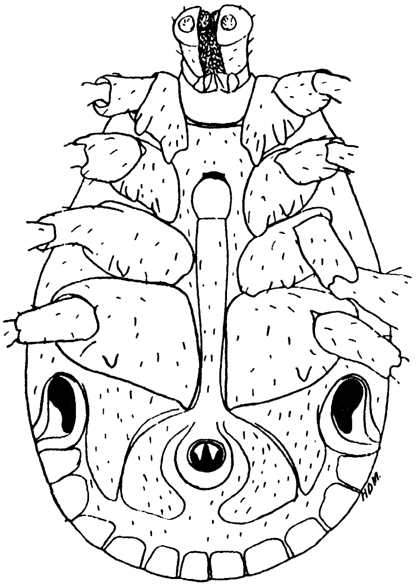

FIG. 262.—*Dermacentor rhinocerotis*, MALE, VENTRAL VIEW. (ORIGINAL.)

H. leporis-palustris Packard, the "rabbit tick," occurs in the United States and South America and transmits Rocky Mountain spotted fever and tularemia (*Pasteurella tularensis*) to man. The infection passes through the egg of the tick.

H. cinnabarina Koch (syn. *H. chordeilis*, Packard) occurs in North and South America and is stated to attack poultry occasionally. It transmits tularemia.

H. humerosa transmits Q fever (*R. burneti*).

H. bispinosum transmits *Babesia gibsoni* of dogs in India.

Genus Dermacentor Koch, 1844

Usually ornate. Eyes and festoons present. Hypostome and palps short. Coxa I bifid and coxa IV of male much larger than coxæ I to III. No plates on ventral surface of male.

D. reticulatus (Fabricius, 1794) occurs mainly in Asia and Southern Europe, more rarely in America. It is parasitic on many domestic and wild mammals. Knuth and du Toit give the following data on the life-cycle, according to Marzinowsky and Bielitzer:

Larvæ hatch	2-3 weeks.
Larvæ engorge	2 days or more.
Larvæ moult	about 2 weeks.
Nymphs engorge	several days.
Nymphs moult	2-3 weeks.

This is a three-host tick which transmits biliary fever of horses (*B. caballi*) and of dogs (*B. canis*), the infection passing through the egg of the tick.

D. andersoni Stiles (syn. *D. venustus* Banks, 1908), the "Rocky Mountain spotted fever tick," occurs in the United States between the Cascade and the Rocky Mountains. The larvæ and nymphs parasitise on practically all available small mammals, especially rodents, while the adults suck blood, mainly on horses and cattle, also on other large mammals and man. Hunter and Bishopp[*] give the following data on the life-cycle:

The females lay about 4,000 eggs.

Pre-oviposition period	7-41 days.
Oviposition lasts	about 30 days.
Eggs hatch	15-51 days.
Larvæ engorge	3-8 days.
Larvæ moult	6-21 days.
Nymphs engorge	3-9 days.
Nymphs moult	over 3 weeks.
Females engorge	8-14 days.
Unfed larvæ survive	21-117 days.
Unfed nymphs survive	300 days or longer.
Unfed adults survive	413 days.

This tick transmits Rocky Mountain spotted fever and tularemia (*Pasteurella tularensis*) to man, as well as equine encephalomyelitis (western type). In all cases the infection passes through the egg of the tick. It also transmits anaplasmosis of cattle and causes paralysis in man and various animals, particularly sheep. In such cases of paralysis the ticks are usually found attached along the back of the neck near the vertebral column. The symptoms develop in the course of about a week after attachment of the tick; there is a progressive paresis of the limbs and usually incontinence of urine at the height of the disease.

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[*] *U.S. Dept. Agric., Bur. of Entomol., Bull. No.* 105. 1911.

D. variabilis (Say), the "American dog tick," which is common on dogs in the United States, and several other species of this genus transmit Rocky Mountain spotted fever. This species also transmits *Anaplasma marginale* of cattle and tularemia to man. The larvæ and nymphæ feed on wild rodents, especially the "short-tailed meadow mouse," *Microtus* spp.

D. nitens Neumann is a small tick which occurs in tropical America, especially on horses.

D. occidentalis Neumann and **D. albipictus** Packard transmit anaplasmosis of cattle.

D. parumapertus marginatus transmits Rocky Mountain spotted fever.

Genus **Rhipicentor** Nuttall and Warburton, 1908

This genus closely resembles *Dermacentor*, but differs from it especially in the following points: it is inornate, the basis capituli is hexagonal dorsally and has prominent lateral angles, and coxa IV in the male bears two long spurs. There are several species, none of which are known to transmit any disease.

Genus **Amblyomma** Koch, 1844

Usually ornate. Eyes and festoons present. Hypostome and palpi long. Male without ventral plates, but small chitinous plaques may be present close to the festoons. The species are usually large and broad.

A. hebræum Koch, 1844, the "bont tick," occurs frequently in the warmer parts of South and Central Africa and is parasitic on all domestic and many wild mammals; the young stages also attack birds. This is a three-host tick. The female lays up to 20,000 eggs.

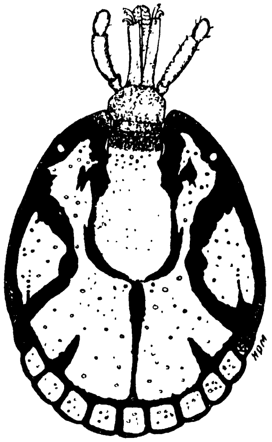

FIG. 263. — *Amblyomma hebræum*, MALE, DORSAL VIEW, NOT SHOWING THE LEGS. (ORIGINAL.)

Pre-oviposition period	6-26 days.
Larvæ hatch	4-13 weeks.
Larvæ engorge	4-7 (-20) days.
Larvæ moult	25-66 days.
Nymphs engorge	4-20 days.
Nymphs moult	21 days to 3 months.
Adults engorge	10-20 days.
Unfed larvæ survive	7 months.
Unfed nymphs survive	6 months.
Unfed adults survive	7-20 months.

The tick attaches usually in the perineal and genital regions of its host and may produce bad wounds. It transmits heartwater (*Rickettsia ruminantium*) of cattle, sheep and goats. The infection does not pass through the egg of the tick. This tick is very resistant to dipping, especially the adult stage.

A. variegatum (Fabricius, 1794), the "variegated tick," is an African species. It feeds on many species of mammals and rarely on birds, and transmits heartwater and Nairobi sheep disease.

A. americanum (Linnæus, 1758), the "lone-star tick," and **A. cayennense** transmit Rocky Mountain spotted fever.

Genus **Aponomma** Neumann, 1899

Eyes vestigial or absent, otherwise resembles *Amblyomma.* The species of this genus occur almost exclusively on reptiles.

TICKS AS PARASITES

Apart from the fact that ticks transmit very important and, as a rule, fatal diseases, their significance as external parasites in warm climates should not be underestimated. The fact that control measures for the diseases transmitted by ticks must be directed in the first instance against the ticks themselves has had the effect of reducing the prevalence of ticks to such an extent that their direct harmfulness is no longer obvious in many countries. Before such control measures as dipping had become a regular practice in tick-infected countries, cases of death from parasitism by ticks were not uncommon. Striking photographs have been published by various authors, showing animals practically covered with thousands of ticks. It is not difficult to imagine how ticks can increase under suitable conditions, seeing that each female lays several thousand eggs, and two or more generations may develop annually.

It has been calculated by du Toit that a female *Ixodes ricinus* ingests on the average at least 0·4 gm. blood; some of the larger species are stated to take ten times as much or even more. The anæmia caused by *Ixodidæ* is therefore as significant as it is in the case of blood-sucking internal parasites, which are considered to be very harmful for this reason alone, while the *Argasidæ*, which engorge themselves repeatedly in their adult stage, are even more important in this respect than the *Ixodidæ*.

Ticks, moreover, are irritating to their hosts, so that severe infections lead to obvious "tick-worry," which results in restlessness, loss of condition, and, in the case of cows, to a marked decrease in the milk yield.

The skin may be so beset with the parasites that its normal functions are probably interfered with and several species, particularly those belonging to the genera *Amblyomma* and *Hyalomma*, produce wounds that damage the skin of the animal or may lead to loss of teats or infection by blowflies. As has been mentioned above, lameness in sheep is frequently caused by *Hyalomma ægyptium* attaching to the feet of the animals.

Treatment and Control of Tick Infection.—Although ticks are in themselves important parasites, and should be combated for this reason, control measures are, as a rule, directed against the diseases of which the ticks are the vectors, and are therefore based on the epizootology of these diseases as well as on the habits of the ticks.

Since ticks attach to various parts of the bodies of animals, treatment has to be applied to the whole body and is usually carried out by dipping the animals in a suitable tank containing the remedy, or dip, in an aqueous solution, suspension or emulsion.

DDT in a concentration of 2·5-5 per cent. has an immediate and lasting effect on the body of an animal against the larvæ and nymphæ of ticks, but is not quite so effective against the adults. The newer preparation "Gammexane" (the gamma isomer of hexachlor-cyclo-hexane) is more effective. It remains to develop a suitable and economical dip containing either of these chemicals, or another method of applying them. Meanwhile arsenical dips are used, sometimes fortified with rotenone or nicotine, and the following information applies mainly to such dips.

Dipping has several disadvantages. The ticks stay on the host, as a rule, for a few days only, thus necessitating very frequent treatment in order to kill all ticks that attach themselves, a procedure to which all classes of animals cannot be subjected. Where wild animals occur these represent a source of food, and serve to keep tick life from being exterminated. All effective dips known at present are poisonous to the hosts, and to human beings as well as to the ticks. For these reasons dipping alone, though very effective in reducing tick incidence to a low level, is, in most cases, not sufficient to effect complete extermination, and other methods of control have to be applied as well if this object is to be achieved.

Arsenical dips are usually employed in concentrations of 0·1, 0·2 and 0·3 per cent. sodium arsenite (80 per cent. As_3O_3), with dipping intervals of 3, 5-7 and 14 days respectively. The sodium arsenite is boiled with a small quantity of water to dissolve and then mixed with the water in the dipping-tank. It is important that the dip fluid should be regularly tested and kept at the correct strength. Animals dipped for the first time should be treated with a weaker solution than the normal, in order to prevent scalding of the skin. This also applies to oxen working in hot weather. The dipping-tank is usually cleaned at intervals of 6 months. The waste fluid should be disposed of in such a way that it cannot cause poisoning of stock.

The exact way in which the arsenical dip acts on the tick is not known, but probably it does not happen in an indirect way through the host. The ticks may not be killed immediately, and engorged females may even lay eggs, but these do not hatch. Apart from killing ticks and most other external parasites, regular dipping produces a healthy skin and coat, and promotes healing of small wounds.

Cattle, horses, dogs, goats and non-wooled sheep can be dipped in the same tank, but wooled sheep must be treated separately lest the wool should become soiled with the hairs of other animals. It is important that all the hosts of the species of tick to be eradicated should be dipped simultaneously. When dipping is carried out against a disease such as East Coat fever, to which only cattle are susceptible, these alone require to be dipped, especially as in this instance infected ticks lose the infection by feeding on non-susceptible animals.

Before dipping the animals are watered so that they should not be thirsty and drink the dip fluid. Either before or after dipping the animals are hand-dressed in order to kill ticks in the ears and under the tail, which parts may escape being wetted by the fluid. The ordinary dip fluid is frequently used or special preparations containing DDT, which have a more lasting effect, may be applied. It is also frequently advisable to clip long hair from the ears or the brush of the tail in the case of cattle.

Various types of dipping-tanks are used in different countries. The " Union type," recommended by the Department of Agriculture in South Africa as the result of many years' experience, has a " swim " of about 40 feet length, and constitutes the optimum of suitability both as regards effective length and expense of construction and filling capacity. From a collecting-pen the animals pass through a narrow crush to the dipping-tank. The crush should be strongly built and have a hard floor to prevent dirt from being carried into the tank. Hand-dressing is done in this crush or in the exit crush. The latter leads from the tank to a drying-pen, and has a hard floor sloping towards the tank so that the fluid carried out by the animals runs back. This fluid may first run into a sump in which dirt settles out. As a rule the " sheer drop " type of inlet to the tank is preferred, since it causes the animals to take a plunge which wets the heads, and frequently also makes them lift their tails Sloping inlets cause less splashing, and are preferable for pregnant animals, but they frequently lead to scraped hocks, and some animals may pass through without wetting the head.

Spraying and hand-dressing are useful for individual cases, such as dogs or animals in the late stages of pregnancy, which cannot be dipped. Arsenical solutions as used for dipping are applied by means of a spray pump or by hand, or suitable DDT preparations could be used advantageously. Frequent grooming of animals dislodges many ticks and thus assists in limiting their number on the hosts.

Grass burning may be effective in killing large numbers of ticks, particularly the larvæ which climb on to the plants, if carried out late in spring. Such fires usually pass over rapidly, and do not kill ticks that have hidden away to moult, nor eggs which were laid in sheltered spots.

Cultivation of land undoubtedly tends to reduce tick life by controlling the movements of domestic and wild animals, as well as by creating conditions unsuitable for ticks, as, for instance, exposure of eggs to sunlight, or burying them deeply by ploughing.

Starvation.—In general this method is not practicable, since ticks live for long periods without food and wild animals may serve as hosts. In a few cases a disease transmitted by ticks, such as East Coast fever, may be eradicated by keeping susceptible animals away for such a period that infected ticks will either have died of starvation or have cleaned themselves by feeding on a non-susceptible animal.

Natural Enemies.—Certain small hymenopterous parasites of ticks, for instance species of *Ixodiphagus* and *Hunterellus*, are known and have been much studied. They parasitise especially the nymphæ, in which they lay their eggs, and which are literally " eaten out " by the larvæ of the parasite. Certain ants as well as birds (*Bubulcus ibis*, *Buphagus erythrorhynchus*, *B. africanus*) destroy a large number of ticks, and specific diseases of the parasites are also known. It is, however, questionable whether biological control by means of parasites and other agents would be able to diminish the number of ticks to a point below which they are no longer important as disease transmitters. It is, for instance, frequently difficult to find a *Rhipicephalus* on cattle which have for some months been regularly dipped in an East Coast fever area, and yet the few remaining ticks may still be sufficient to cause cases of the disease.

Infected buildings, such as stables and kennels, or railway trucks and ships, may be cleaned of ticks by thorough fumigation with cyanide. Where such treatment is not possible, all litter has to be removed and the buildings can be sprayed with a suitable preparation of DDT or pyrethrins.

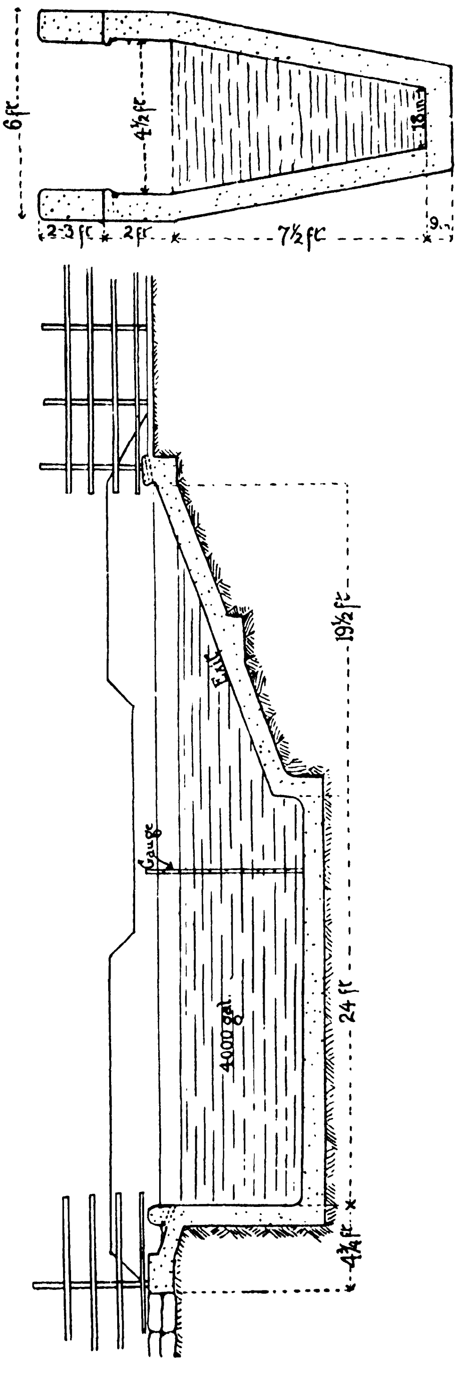

Fig. 264.—Section of Cattle-Dipping Tank, Union Type (as recommended by Union Department of Agriculture).

Super-Family SARCOPTOIDEA

This group includes a large number of species which are mostly free living and small in size. A few species are important parasites or vectors of disease. Morphologically they are closely allied to the ticks. The legs are frequently grouped in two pairs on either side in the nymph and adult and they end in suckers, claws or hairs.

Family SARCOPTIDÆ

Genus **Sarcoptes** Latreille, 1806

The mites belonging to this genus are parasitic on a number of different domestic and wild mammals, causing a disease known as mange, and they are regarded by some authors as belonging to different species or by others as varieties of the species *S. scabiei*, which are specific to their hosts. It has, however, been found possible to transmit the mites from various species of hosts to others, so that they might be considered as host varieties in process of evolution, but still able to pass from one species to another. This point is one of great practical importance in connection with control measures, since sarcoptic mange is a scheduled disease in most countries.

Sarcoptes scabiei is a minute parasite, roughly circular in outline, characterised by the presence of suckers with unjointed pedicles on the first two pairs of legs in the male and female, and on the fourth pair in the male, while the third and fourth pairs of legs are short in both sexes, and do not project beyond the margin of the body. The dorsal surface is covered with fine folds and grooves mainly transverse in arrangement, and bears a number of small triangular scales. The female bears on either side of the mid-line anteriorly three short spines and posteriorly six longer spines with bifid tips, in addition to a few hairs.

Life-Cycle.—The life-cycle of this parasite is not completely known. The female burrows into the skin and lays 40-50 eggs in the tunnel it forms. Gordon, Unsworth and Seaton* studied the life-cycle of the closely related *Notœdres* on white rats and believe that the life-cycle of *Sarcoptes* is very similar. They found that the majority of the larvæ, which have three pairs of legs, escape from the breeding tunnels and wander on the skin, but some remain in the parent tunnel or side pockets of it and continue their development there as far as the nymphal stages. Of those that reach the surface many perish; others burrow into the stratum corneum to construct almost invisible moulting pockets, in which they also feed. There are two nymphal stages which may stay in the larval pockets or wander and make new pockets. The nymphs have

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* *Ann. Trop. Med. Par.*, 37 (3-4): 175-194. 1943.

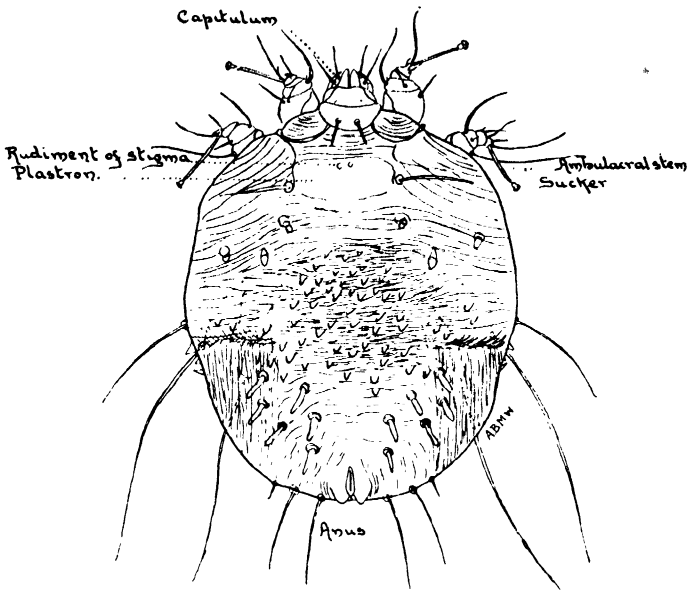

Fig. 265.—*Sarcoptes scabiei*, Dorsal View of Female. (After Bedford, Modified.)

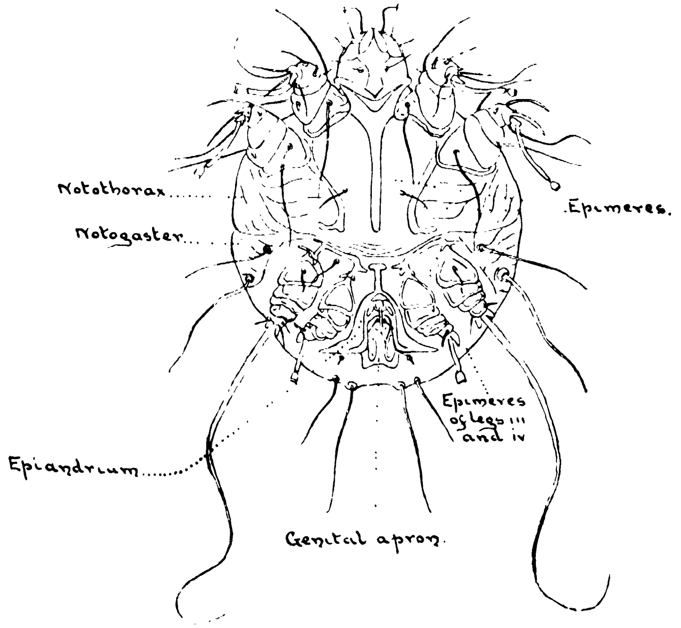

Fig. 266.—*Sarcoptes scabiei*, Ventral View of Male. (After Bedford.)

four pairs of legs, but no genital apertures. Finally, males and females are produced, the development from the time the eggs are laid lasting about 17 days. The adult female remains in the moulting pocket until fertilised by a male. She then extends the pocket into a tunnel or makes a new one and, after 4-5 days, begins to lay eggs, 3-4 a day. The female probably does not live longer than 3-4 weeks. Infection is spread mainly by the wandering larvæ, nymphs and fertilised young females.

The mites are very susceptible to dryness and cannot live more than a few days off their host. Under optimal laboratory conditions the mites have been kept alive for 3 weeks. The investigations of du Toit and Bedford have shown that infected kraals which are left empty are free of infection after 17 days.

Pathogenesis.—The parasites pierce the skin to suck lymph and may also feed on young epidermal cells. Their activities produce a marked irritation which causes intense itching and scratching, which aggravates the condition. The resulting inflammation of the skin is accompanied by an exudate which coagulates and forms crusts on the surface, and is further characterised by excessive keratinisation and proliferation of connective tissue, with the result that the skin becomes much thickened and wrinkled. The hair falls out as a consequence of the altered condition of the skin and lack of nourishment.

Symptoms.—*Sarcoptes* prefers those parts of the body that are not covered by much hair, such as the face and ears of goats, sheep and rabbits, the hock, elbow, muzzle and root of the tail in dogs and foxes, the head and neck in equines, the sacral region and the neck in cattle, and the back of pigs. When the disease is allowed to spread, all parts of the body may eventually become affected. The disease is rare in wooled sheep. The local symptoms are obvious from the pathogenesis; the skin is more or less bare, thick and wrinkled and covered with dry crusts. In young lesions there are red papules or vesicles and fresh exudate. The lesion is exceedingly irritating and causes much biting and scratching. Small foci of mange have little or no effect on the general health of the host, but larger lesions produce progressive emaciation and even death. It is important to note that mange is a disease of poor-conditioned animals, and is therefore most frequently seen towards the end of winter and in early spring. The fact that animals in good health and condition are rather resistant to the disease may account for many cases of unsuccessful experimental infection.

Diagnosis.—The lesion is scraped by means of a knife until the moist layers of the skin are exposed and the material is examined for the presence of the parasites (p. 16).

Differential Diagnosis.—In dandruff the skin is soft and pliable and no parasites are found. Ringworm does not cause thickening of the skin either, while the fungus spores can be found in the shafts of the hairs. Lice may produce crusts and matting of the hair, but they are readily detected and as a rule the skin is not thickened. Psoroptic, notœdric and chorioptic mange usually occur on other parts of the body and can be recognised by the different appearance of the parasites. Demodectic mange does not itch and pustules are frequently present in the lesions; moreover, the parasites are easily recognised. Harvest mites (*Trombidiidæ*) cause scaly lesions from which the hairs fall out and are found mainly on the heads of animals that run on pasture; the skin remains soft and the mites, which are larval forms, have a scarlet-red colour.

Treatment.—Mange is not easily cured, and must therefore be very thoroughly treated. Infected animals should be isolated and their quarters thoroughly disinfected. A method of fumigating large animals with sulphur dioxide has been described. The animal is placed in a special fumigating box with only the head emerging and the body is subjected to the action of the gas. This method is useful where cases occur frequently and for extremely bad cases which it is rather hopeless to treat in any other way.

During recent years several effective remedies for scabies have been developed. In all cases it is necessary to prepare the animal, or the lesion, for treatment by clipping the hair if it is long, followed by thorough washing and scrubbing with warm water and soap in order to remove the scabs. Animals in poor condition and badly affected with mange should not be completely treated at once, but one half or a quarter of the body can be treated at a time, since the lesions do not spread rapidly.

The following remedies are recommended, and the choice will depend largely on the kind and number of animals to be treated:

1. *Lime-sulphur dip* containing 1·5 per cent. polysulphide sulphur is applied as a spray or by means of a brush. Treatment is repeated 3-6 times, as required, at weekly intervals.

2. *Hypo* (sodium thiosulphate) is applied as a 30-60 per cent. aqueous solution by means of a brush and allowed to dry for 1-2 hours. Then 10 per cent. commercial hydrochloric acid is brushed on so as to cause the liberation of active sulphur from the hypo. Repeat 2-3 times as the case demands, after washing, with intervals of 3 days.

3. *Rotenone* is used in the form of a derris-root suspension (120 gm. in 4,500 c.c. water with 30 gm. soft soap) after this has been allowed to stand overnight. Three treatments with intervals of 2 days each.

4. *Dimethyl-diphenyl-disulphide* (dimethylthianthrene, Mitigal). Four applications are given in 10 days.

5. *Benzyl benzoate* is used as an emulsion or mixed with equal parts of

soft soap and isopropyl alcohol or methylated spirits. It is painted on and allowed to dry. Repeat if necessary.

6. *Tetraethylthiuram monosulphide* (Tetmosol) is used as a freshly-prepared watery solution, usually 5 per cent. This remedy is very effective and a 20 per cent. Tetmosol soap, used for ordinary washing and bathing, has given good results in human beings.

DDT preparations are not effective.

Good feeding and exercise are valuable additional measures. Spontaneous recovery is not uncommon in animals that are well fed and cared for.

Prophylaxis.—All infected premises should be cleaned out and disinfected by spraying with a strong carbolic solution, paraffin emulsion or lime-sulphur dip, and they are best left unused for 14-17 days. Utensils such as curry-combs, brushes and harness should also be disinfected or locked up for 3 weeks, when the mites on them will have died.

Genus **Cnemidocoptes** Fürstenberg, 1870

C. gallinæ (Railliet, 1887) is a small mite, resembling *Sarcoptes*, which causes "depluming itch" in fowls. The mites burrow into the skin alongside the shafts of the feathers and cause an itching, inflammatory condition. The feathers break off readily and they are pulled out by the birds, which may in this way acquire the vice of feather eating. The lesions are mostly seen on the back and wings, more rarely on the head and neck.

Diagnosis can be made by pulling out a few feathers at the edge of the lesion and searching for the mites on them.

Treatment.—The birds are dipped in a mixture of sodium fluoride, sulphur, soap and water as for lice, or sulphur ointment can be applied to the lesion in individual cases. DDT may be useful.

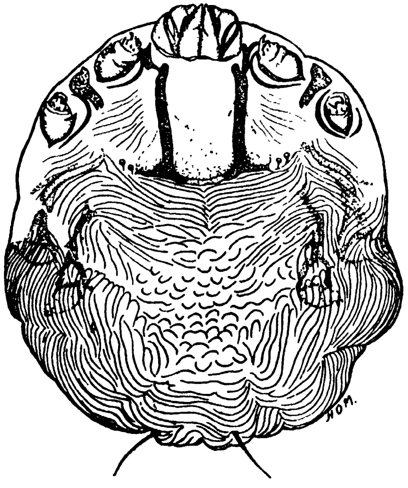

FIG. 267.—*Cnemidocoptes mutans*, DORSAL VIEW OF FEMALE. (ORIGINAL.)

C. mutans (Robin, 1860) causes the condition known as "scaly leg" in fowls and turkeys. The mites apparently get on to the feet of the birds from the ground, since the lesion usually develops from the toes upwards. The parasites pierce the skin underneath the scales, causing an inflammation with exudate that hardens on the surface and displaces the scales. This process, accompanied by marked keratinisation, is responsible for the thickened scaly nature of the skin. The disease may lead to lameness and malformation of the feet. In rare cases the comb and neck may be affected.

Treatment.—Two methods of treatment are recommended and they are both effective. According to one method, the legs are dipped in paraffin (kerosene) to soften and the scales are removed as much as possible by rubbing with the fingers. Only the scaly part of the leg should be moistened, as paraffin irritates the skin. The legs are then smeared with 10 per cent. sulphur in soft fat. The other method, recommended by Haupt (1931), consists of bathing the legs three times, at intervals of 2-4 weeks, in a 0·5 per cent. solution of sodium fluoride. Infection on the comb and neck can be treated with sulphur ointment. The fowl-house, and especially the perches, should also be disinfected.

Genus **Notœdres** Railliet, 1893

N. cati Hering, 1838, is a minute mite which attacks mainly cats and rabbits. Possibly there are different varieties of the parasite on the two hosts. The mites burrow into the skin, causing mange-like lesions on the face and ears, more rarely also on the legs and genitalia.

The mite resembles *Sarcoptes* very closely, but the anal opening is situated dorsally and not terminally, as in the latter genus.

Treatment and *Prophylaxis* as in the case of *Sarcoptes.* Cats can be controlled for dipping by placing them in a suitable linen bag with a number of holes through which the fluid can enter; the head of the cat is left out and is moistened by means of a swab. Saxinger* recommends a solution of hypo (sodium thiosulphate), to which acid is added in order to set free sulphur dioxide and fine particles of sulphur. Small lesions can be treated by moistening with carbon tetrachloride.

Genus **Psoroptes** Gervais, 1841

This genus contains a number of parasites which live on different hosts and, contrary to the state of affairs in the case of *Sarcoptes*, these are specific to their hosts and can be regarded as different species or varieties, although morphologically they may be difficult to distinguish. They are oval in shape and the tarsal suckers have jointed pedicles. As a rule these parasites live on the skin of parts of the body that are well covered with hair or wool or in the ears of their hosts and cause the condition known as " scab " in sheep or " mange " in other animals.

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* *Deut. Tier. Wschr.*, 39 (18): 275-276. 1931.

P. communis ovis Railliet, 1893, is the cause of sheep-scab, an important disease which occurs in many countries. The parasite cannot be transmitted to other species of animals. The different stages of development include eggs, larvæ, nymphæ, males, pubescent females and ovigerous females. The mites are oval in shape and have a white body

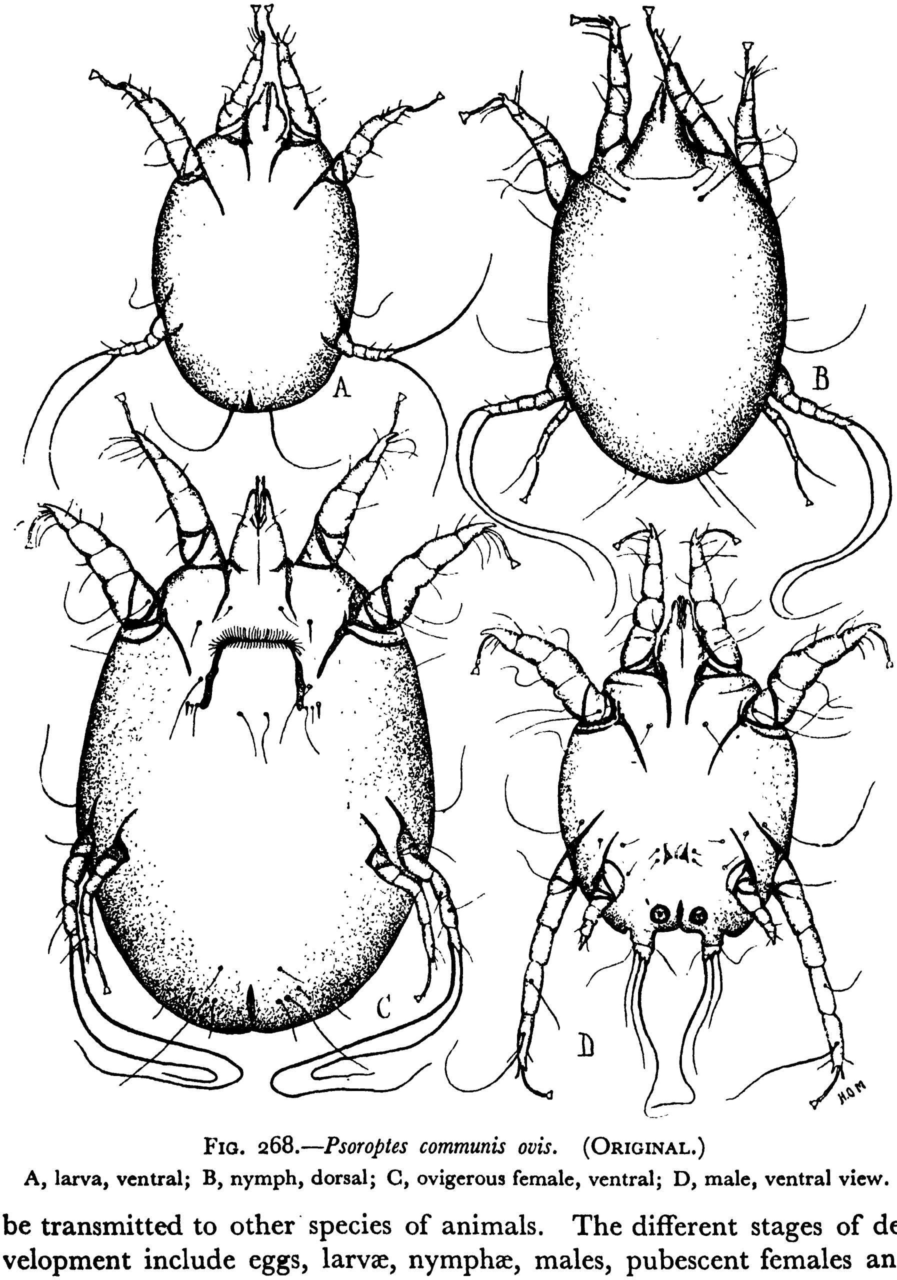

FIG. 268.—*Psoroptes communis ovis.* (ORIGINAL.)
A, larva, ventral; B, nymph, dorsal; C, ovigerous female, ventral; D, male, ventral view.

with brownish legs. The larvæ have three pairs of legs and the other stages four pairs. All bear suckers with jointed pedicles on the first and second pairs of legs; the larvæ have two long bristles on the third pair; the nymphæ, pubescent females and ovigerous females have bristles on the third pair and suckers on the fourth; the third pair of the male is long and suckered, while the fourth pair is very short and bears only hairs. The nymph has no genital aperture. The pubescent female is provided with a pair of posterior copulatory tubercles which are absent in the ovigerous female, while the latter has a wide genital aperture on the anterior aspect of the ventral surface. The male has posteriorly, on the ventral surface, a pair of brown copulatory suckers and terminally a pair of large tubercles which each bear several hairs. The dorsal surface of the body is devoid of scales and spines, but the cuticle shows very fine striations.

Life-Cycle.—The eggs are laid on the skin at the edges of the lesion and hatch normally in 1-3 days. Eggs separated from the skin by crusts may hatch in 4-5 days. Eggs removed with wool from the body or drawn away from the skin to the extent of several centimetres may hatch up to 10 days after having been laid, or otherwise die.

The larvæ feed and, 2-3 days after hatching, moult to the nymphal stage, passing the last 12 hours in a state of lethargy. The nymphal stage lasts 3-4 days, including a lethargic period of 36 hours before the moult occurs. The smaller nymphæ usually become males. As a rule the pubescent females appear before the males, sometimes as soon as 5½ days after hatching, while the males do not appear before the sixth day. Copulation begins soon after ecdysis and lasts 1 day; if there are many more females than males, the period may be shorter. As a rule the proportion of males to females is 1-2 : 4. The pubescent female moults 2 days after the commencement of copulation and the ovigerous female begins to lay 1 day later or 9 days after hatching from the egg. The shortest period observed is 8 days. Even in winter, on sheep that are well clothed, as is usually the case, the cycle is not longer.

The female lays about five eggs daily and a total of 90 or more, living 30-40 days in this stage. A pubescent female was kept alone on a sheep for 42 days. The males live up to 34 days on the host. Off the host, the mites kept in moist jars with wool and crusts at room temperature mostly died within 10 days; some ovigerous females lived longer and one survived for 20 days.

Infected kraals left empty were found to be free of infection after 17 days.

Pathogenesis.—The mites puncture the epidermis to suck lymph and stimulate a local reaction in the form of a small inflammatory swelling richly infiltrated with serum. The latter exudes on to the surface and coagulates, thus forming a crust. The altered conditions cause the wool to become loose and to fall out, or it is pulled out by the sheep in biting and scratching the lesion, which itches severely. The bare crusty patches are unsuitable for the mites, which therefore migrate to the margins of the lesion and thus extend the process outwards. The diseased condition of the skin, and probably also the constant irritation, lead to progressive emaciation and finally death of the sheep.

Symptoms.—Scab lesions may occur on all parts of the body that are covered with wool or hair, but occur most frequently around the shoulders and along the sides of the body in wooled sheep, and along the back, the sternum and the dorsal aspect of the tail in hairy sheep.

In the case of young lesions the wool is disturbed over the lesion as a result of the biting and scratching of the sheep, and usually has a lighter colour than the surrounding wool. A lesion of 2-4 days old appears as a small papule, about 5 mm. in diameter, with a yellowish colour and a moist surface; the mite will as a rule be found on the affected spot. From about the fifth day onwards the exudate begins to coagulate, forming pale yellow crusts, and the lesion extends outwards as the number of parasites increases. Older lesions are easy to detect on account of the loss of wool and presence of scab, while the mites are producing fresh foci in the surrounding covered parts. In some cases large portions of the body may be affected around an old lesion without showing on the surface. If the wool is opened, it is found to be matted together above the skin by scabs, underneath which numerous parasites are located.

In hairy sheep the scab lesion is, as a rule, drier than in wooled sheep, probably on account of more rapid evaporation, and the mites are not as easily found.

Suitable conditions for the development of the disease are: poor condition of the host, dry (*i.e.*, not greasy) wool and moist weather which causes increased egg production. The lesions develop more slowly during dry weather in sheep that are in good condition and particularly in those with greasy wool. So-called " latent " cases, in which a small lesion may exist for months, are seen in the latter type of animal, or in rams in which small dry lesions may occur on the scrotum, in the perineum, along the sheath, on the sternum and at the bases of the horns. In all types of sheep the mites are frequently found in the ears, the inguinal folds, and in the infraorbital fossæ, where they may hide away for long periods. These latent lesions and hiding-places of the mites are exceedingly important in connection with diagnosis and control. In England Downing* found that scab is most active in autumn and winter, while latency tends to occur in summer, on account of less active feeding and decreased oviposition by the mites. He concludes that autumn dipping would lead to the extermination of scab, while in summer dipping must be accompanied by hand-dressing to be effective.

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* *Journ. Comp. Path. Therap.*, 49 (2 and 3): 163-209. 1936.

Diagnosis.—This is a difficult matter and one of the greatest obstacles in the way of complete eradication. It is relatively simple to diagnose the active disease in a scabby flock, but the latent lesions described above make it a difficult matter to declare a large flock free of scab.

In examining a flock, the animals should be closely herded together so that they become warm and the mites are stimulated to move about. The animals are watched for scratching and biting, and all such cases are examined as well as animals with uneven or picked wool or bare spots, while those that rub their heads may have mites in their ears, infra-orbital fossæ and at the bases of the horns. In addition, all rams should be thoroughly examined and also as large as possible a number of the best-conditioned animals, particularly such with greasy wool. These latter sheep are best placed on a table or large box; the fingers of both hands are dug into the wool and the skin is palpated over a large area around the shoulders and the sides of the body. The lesions, even very recent ones, can be easily felt by anyone who has a little experience. To make a definite diagnosis the mites should be found and a hand lens or microscope should be used in case of doubt, but generally examination with the naked eye is sufficient after a little practice. If the mites cannot be found in a dry, crusty lesion, a scraping has to be taken for further examination (p. 16). In sheep that have been effectively treated for scab it is rare to find cuticular skeletons of mites in scrapings, and they will probably not be found for long afterwards.

Differential Diagnosis.—Lice produce scabs and matting of wool or hair, but the insects are readily detected and the lesions do not possess the moist, exudative character of active scab lesions. Ked bites usually have a small hæmorrhagic centre and are small local lesions which do not spread. Grass seeds frequently penetrate the skin and may cause small festering wounds; as a rule the seeds are found in the lesions. Mange is rare in wooled sheep and occurs chiefly on the less covered parts of the body; it has a drier appearance with thickening of the skin and must be differentiated from scab by the different appearance of the parasites. Harvest mites may produce scaly lesions on the face and ears and are easily recognised on account of their red colour. Lumpy wool a condition due to a fungus which causes the wool to become matted and curled together in small tufts, as well as other skin diseases, may cause difficulties, but can be differentiated on account of the absence of the parasite and the different appearance of the lesions. Free-living mites, such as those occurring in manure, may occasionally be found on sheep, but they are more active than *Psoroptes* and can be easily recognised under the microscope. Anæmia or emaciating conditions as caused by worm parasites or febrile diseases frequently cause loss of wool; in these cases the skin is, however, not affected as in the case of scab.

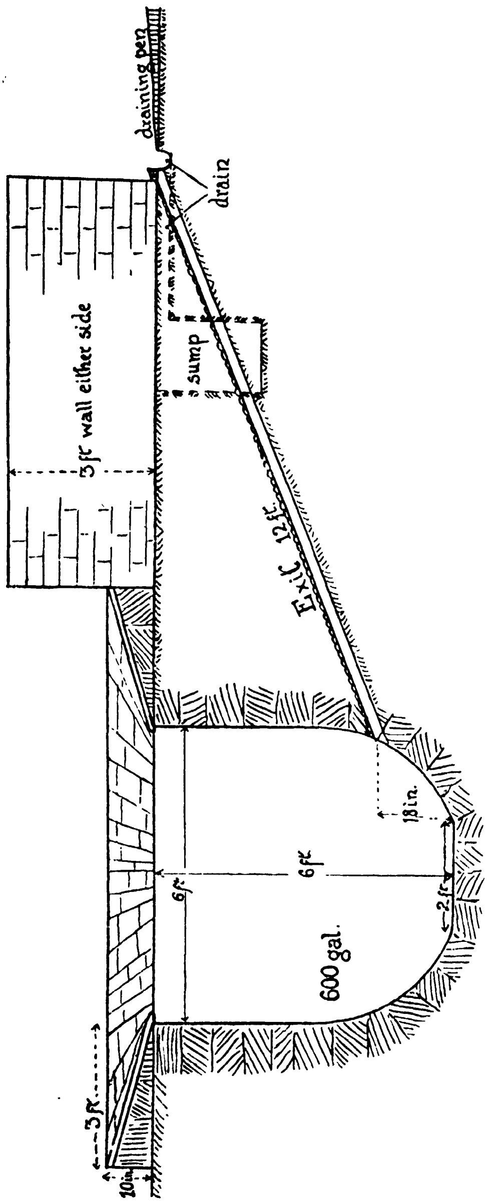

Fig. 269.—Sheep-Dipping Tank, Section (as recommended by Union Department of Agriculture).

Treatment consists in dipping the sheep in a suitable dip and hand-dressing bad lesions as well as the hiding-places of the mites.

Various types of dipping-tanks are employed. In South Africa the circular type is preferred for various reasons. It has been found that the sheep must be kept in the dipping fluid for fully 2 minutes, and the long type of tank which can meet this requirement is expensive to construct and to fill, although it is useful where very large flocks have to be treated. The circular tank allows one operator to have all the sheep constantly under observation. A central pillar is frequently built in the tank so that the sheep can be kept swimming in one direction. The approach to the tank consists of collecting-pens, a crush and other constructions which help in rapid handling of the sheep. The exit has a backwardly sloping floor and leads to a drying-pen, from which the dip flowing off the animals returns to the tank through a sump.

A large number of different dipping fluids are used in some countries, and this fact undoubtedly militates against effective treatment and control. It is obvious that it is impossible to control the efficacy of a few hundred different types of dips. Arsenical, nicotine and lime-sulphur dips of sufficient strength are suitable, while carbolic dips are not as a rule completely effective. DDT preparations may be effective. In South Africa only lime-sulphur dips which contain at least 1·5 per cent. polysulphide sulphur are officially recognised. The dip can be home-made by mixing 7·5 kilos good quality slaked lime with 12·5 kilos flowers of sulphur (15 lbs. lime to 25 lbs. sulphur) into a paste with water, and boiling it in a suitable vessel with 50-100 litres of water until a deep orange-purple solution is obtained. The fluid is strained through a cloth or sack, and made up to 500 litres with water for every 12·5 kilos sulphur used (100 gallons for 25 lbs.).

All the sheep of a flock must be dipped at the same time. They are first watered and the bad cases are picked out for special treatment and marked so that they can be recognised again later. They should be shorn if necessary. All scabs are broken up and removed by scrubbing with a suitable object and then the lesions are moistened with dip fluid. Either before or after dipping, the ears, infraorbital fossæ and bases of the horns of all sheep should be hand-dressed by applying a mixture of two parts oil and one part paraffin (kerosene) or 5 per cent. sulphur in oil by means of a suitable brush.

The animals are dipped for fully 2 minutes, employing a stop-watch or a reliable sandglass. They should be kept moving in the fluid and the heads are immersed a few times.

The dipped sheep should not be returned to infected yards or pens. The treatment is repeated after 9 or 10 days, when any eggs that escaped killing by the first treatment will have hatched and no larvæ will yet have become mature, since those that hatch within 2 days after dipping are killed by the dip still in the wool. Badly infected flocks should preferably be dipped three times.

Difficulties of Scab Eradication.—The difficulties connected with diagnosis have already been described. In mountainous areas and in African native territories it is frequently not possible to collect all the sheep for treatment, and they are sometimes purposely hidden away because the seriousness of the disease is often not realised. Transport of sheep in vehicles and particularly on foot at times of drought or where they are moved for winter grazing is liable to spread the disease over a large area. Cold weather or poor condition of the animals and in some localities even scarcity of water may necessitate postponement of the treatment, and meanwhile the disease spreads unless strict control is maintained. The personal element which is often responsible for laxity and a lack of thoroughness in the treatment has led the governments of various states to undertake complete control of all activities in connection with the eradication of this disease.

P. communis capræ occurs in the ears of goats and sometimes produces lesions. The parasites can be killed by the application of two parts oil and one part paraffin (kerosene).

P. communis equi is found on the horse, causing mange-like lesions, though not with marked thickening of the skin, on the covered parts of the body such as the dorsal aspect of the neck, the base of the tail and the saddle region in riding-horses. From these centres the disease may spread to other parts of the body.

Diagnosis is made as in the case of mange. The parasites resemble the sheep psoropt.

Treatment as for sarcoptic mange.

P. communis bovis and **P. natalensis** produce scab lesions around the base of the tail in cattle, on the " escutcheon " above the udder in cows or the " twist " in bulls and oxen, and more rarely on the neck and shoulders.

Diagnosis and Treatment as in the case of sarcoptic mange.

P. communis cuniculi occurs mainly in the ears of rabbits, producing thick crusts, and the disease may extend on to the head and body, becoming very serious where it is neglected. Torticollis and spasms of the eye muscles may occur.

Diagnosis is made by finding the parasites in the scrapings. The disease must be differentiated from sarcoptic and notœdric mange.

Treatment.—Any of the preparations recommended for otodectic mange may be applied after the crusts have been removed, while the infected quarters should be cleaned and disinfected at the same time.

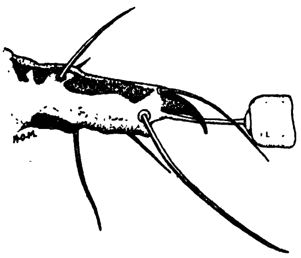

FIG. 270. — *Chorioptes*, EXTREMITY OF LEG WITH SUCKER. (ORIGINAL.)

Genus Chorioptes Gervais, 1859

The different species of this genus live on the skin of several species of domestic mammals, causing chorioptic mange. The parasites resemble *Psoroptes*, but the tarsal suckers have unjointed pedicles.

C. equi (Gerlach, 1857) occurs on the feet of horses, usually about the fetlock, and particularly in horses with long hairs (feather) in this region, rarely on parts of the body above the hock or knee.

Life-Cycle.—Similar to that of *Psoroptes*, but not satisfactorily known.

Significance.—The parasites produce "foot mange" or "itchy leg" with scab-like lesions which are perhaps in themselves not very important, but, on account of their itching nature, cause the animals to rub, stamp, scratch and bite the legs and to kick frequently, particularly at night. It is maintained by some authors that the condition often leads to grease, fractures and other diseases of the legs and feet of horses, on account of the jarring and bruising that are liable to occur.

Diagnosis.—The parasites can be found in scrapings taken from the lesions.

Treatment.—The hair has to be clipped from the lesion and its surroundings and the feet bathed for a few minutes in warm lime-sulphur dip. The treatment should be repeated a few times at 10-day intervals. The stable should at the same time be properly cleaned and sprayed with lime-sulphur dip, and curry-combs and brushes need to be disinfected.

C. bovis produces lesions on the legs, around the base of the tail and more rarely in the sacral region of cattle.

Diagnosis and *treatment* as in the case of *C. equi.*

Genus **Otodectes** Canestrini, 1894

O. cynotis (Hering, 1838) occurs in the ears of the dog, cat, fox and ferret, causing ear mange or otodectic mange. The parasites resemble *Chorioptes*; they have tarsal suckers with unjointed pedicles on the first and second pairs of legs in the female and on all four pairs in the male. The fourth pair of legs in the female is small. In the male the copulatory tubercles are not prominent.

Life-Cycle.—Similar to that of *Psoroptes*, but not satisfactorily known.

Pathogenesis and Symptoms.—The parasites live in the ears of their hosts, sometimes also spreading to the outside. They pierce the skin to suck lymph and so produce an inflammation with exudation of serum and formation of crusts. The symptoms are seen in dogs at an earlier stage than in cats and foxes, which usually do not appear to be affected until the disease has reached an advanced stage. The animal shakes its head and scratches the ears in ordinary cases, while in more advanced stages the ears droop and there is a discharge. There may be torticollis or the animals turn about in a circle, and even more marked nervous symptoms like epileptiform fits may be seen. If the disease is allowed to take its course, a purulent inflammation of the external ear frequently sets in and perforation of the tympanic membrane may occur as the result of ulceration, leading to serious affections of the middle and inner ear and the brain.

Diagnosis.—After removal of the crusts, the mites are readily found in material scraped from the skin of the external ear passage. They must be differentiated from *Sarcoptes scabiei* and *Notœdres cati*.

Treatment.—The ear has to be cleaned as well as possible and its external surface and surroundings should be washed with a suitable disinfectant, taking into account the value of the skin in case of foxes, for which Hanson recommends an 8 to 10 per cent. derrisine solution. For application to the inside of the ear the following mixtures are recommended by various authors: (i.) Carbon tetrachloride 1, castor oil 4; (ii.) iodoform 1, ether 10, cotton-seed oil 25; (iii.) naphthol 1, ether 3, cotton-seed oil 10; (iv.) iodine crystals 1, phenol crystals 3, glycerin 60, heated to dissolve the iodine completely. DDT preparations may be useful. The mixture is introduced into the ear, which is then manipulated so as to distribute the material to all parts. The treatment should be repeated after 7-10 days.

Family CYTOLEICHIDÆ

Genus **Cytoleichus** Megnin (1879) (syn. *Cytodites*)

C. nudus (Vizioli, 1870), the "air-sac mite," is a small, oval, creamy-coloured mite with suckered legs and practically no hairs, which lives in the respiratory passages and air-sacs and has also been found in other organs of fowls, turkeys and pheasants. The life-cycle is unknown, but the parasites are probably spread by mucus from the respiratory passages which is coughed up or passed with the fæces.

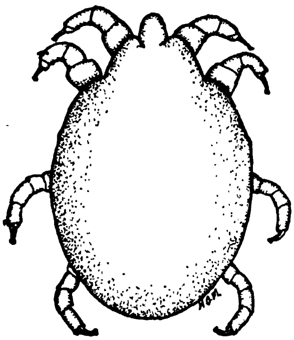

FIG. 271.—*Cytoleichus nudus*, DORSAL VIEW. (ORIGINAL.)

As a rule the parasites are not pathogenic. In South Africa this mite is very common, but it has not been recorded as a cause of disease. Turbet (1929) incriminates it as causing serious mortality in fowls in Fiji, and other authors state that it weakens the lungs and thus forms a predisposing factor for pneumonia and pulmonary tuberculosis. It appears probable that the presence of a number of these parasites in the lungs could have such an effect.

Diagnosis.—At the present stage of our knowledge a definite diagnosis can be made only at autopsy.

Treatment.—No effective remedy is known. Where the infection becomes a serious matter it would be advisable to kill off the infected birds, and leave the runs and houses empty for a few weeks after they have been cleaned and sprayed with paraffin or lime-sulphur dip.

Genus **Laminosioptes** Megnin

L. cysticola (Vizioli, 1870), the "subcutaneous mite" of the fowl, is a small oval parasite; the anterior two pairs of legs each end in a claw, and the posterior two pairs each in a claw and suckerless pedicle.

Life-cycle unknown. Since the mites live in the subcutaneous tissues of their hosts, it is indeed difficult to imagine how the infection spreads from one bird to another, but a free-living stage is bound to occur.

Significance.—The live parasites are rarely seen, but they may be found in the subcutaneous tissues. Usually the presence of the parasites is only indicated by the occurrence of small, flat, oval nodules, which resemble bits of fat in the subcutis. These nodules have a caseous or calcified content and are formed around the dead mites, of which the remains may still be present. The parasites are not pathogenic, but large numbers of these nodules may reduce the value of birds intended for human consumption.

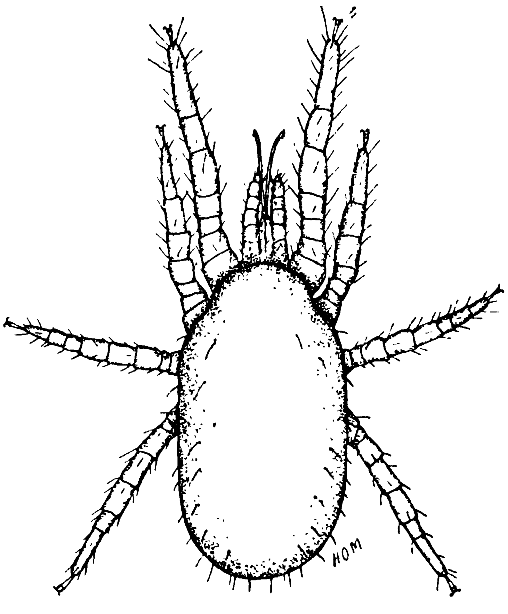

FIG. 272.—*Dermanyssus gallinæ*, FEMALE, DORSAL VIEW. (ORIGINAL.)

Treatment and *Prophylaxis* unknown.

Super-Family PARASITOIDEA

Family DERMANYSSIDÆ

This family includes a few important parasitic mites known commonly as "red mites."

Dermanyssus gallinæ (Redi, 1674) and *Liponyssus sylviarum* Canestrini are the common red mites of poultry and other birds in Europe and North America.

L. bursa Berlese, 1888, the "tropical fowl mite," is found in many warm countries and attacks birds.

L. bacoti (Hirst, 1913), the "tropical rat mite," is frequently carried by rats into stables and human dwellings, where the mites attack domestic animals and human beings. This species occurs in many warm countries. The red mites have relatively long legs and mouth parts and bear a moderate number of short hairs. Adult females measure up to 1·5 mm. in length and the mites have a blood-red colour after having engorged.

Life-Cycle and Habits.—The eggs are laid in crevices of walls or woodwork, rarely on the birds, and hatch in 2 days under favourable conditions. The larval and nymphal stages feed and hide away to moult, each stage lasting about 2 days. The whole cycle may be completed in 7 days under the best conditions. The adult mites have habits like *Argas persicus*, attacking their hosts for short periods to feed and then hiding away in suitable places such as cracks of woodwork or under boxes standing on the ground, and they may also be found under the displaced scales on the legs of fowls affected with " scaly leg." Under experimental conditions the mites lived over 1 month without food.

The mites reproduce at a remarkable rate when conditions are favourable, and they may therefore become a serious pest, producing anæmia in fowls and causing much irritation to their hosts. *D. gallinæ* transmits fowl spirochætosis (*Spirochæta anserina*) and *L. bacoti* transmits endemic typhus of man.

Diagnosis.—The mites can easily be found in the fowl-house or stable, since they are visible with the naked eye and their red colour is characteristic. Anæmia of poultry may also be caused by the following external parasites which do not remain on the host: *Argas persicus*, *Simulium* and *Cimicidæ*.

Treatment.—As in the case of *A. persicus*. Birds should be placed in crates which are scalded every day or two with boiling water for about 10 days while the fowl-house is being cleaned. Since some mites may still remain on the fowls with this method, it is preferable to dip the birds in a carbolic dip. Special attention should be given to birds with scaly legs. Painting the perches and their supports with nicotine, as for lice, also gives good results. Infected human dwellings and, if possible, also stables are best fumigated with cyanide.

Prophylaxis.—Rats and wild birds which may introduce the mites should be checked. The mites may also be introduced with hay or straw and suitable measures must be taken to obtain clean material. New birds have to be examined for the presence of these mites and treated if necessary before they enter the fowl-house.

Genus **Pneumonyssus** Banks, 1901

P. caninum Chandler and Ruhe, 1940, is a mite which inhabits the nasal passages and sinuses of the dog. Only females have so far been found. They are oval in shape, measuring 1-1·5 by 0·6-0·9 mm., and their colour is very pale yellow. The cuticle is smooth with scant setæ and bears a roughly leaf-shaped, irregular dorsal plate; a sternal plate is not present; the anal plate is very slightly chitinised and bears three setæ, two antero-lateral and one posterior. The first pair of legs are stronger than the others and bear strong tarsal claws; the other three pairs of legs bear slender pedicels, small claws and delicate pulvilli. The palpi consist of five segments and each bears two terminal setæ; the cheliceræ are chelate. The club-shaped peritremes are situated ventro-laterally between the third and fourth pair of legs. The vulva is a transverse slit between the fourth coxæ. Mature females often contain eggs with fully developed larvæ and are probably viviparous.

Several cases have been described from the U.S.A., but no apparent symptoms due to the infection have been noted, except a slight catarrhal sinusitis and rhinitis in some of them.

Family CHEYLETIDÆ

Genus **Psorergates** Tyrrell, 1883

P. ovis Wormersley, 1941, was described as a parasite of sheep by Carter* from Australia. The mites are almost spherical, with the sides slightly indented between the legs. The legs have paired claws and the palpi are short and conical. Female, 189 by 162 μ, bears ventrally, near the posterior end, two pairs of long setæ arising from a pair of lobes. Male, 167 by 116 μ, bears one pair of setæ arising ventrally near the hind end from a median tubercle; penis situated dorsally in the anterior half of the body. Eggs spherical, 48 μ in diameter.

Life-Cycle.—Little is known; probably the whole cycle is completed on the sheep.

Pathogenesis and Symptoms.—The parasites have so far been found only on fine-wooled merino sheep. They cause a mild irritation which leads to occasional biting and scratching, so that the wool is disturbed in affected areas, showing a pale tip or even tufts which have been pulled out. The wool growing on affected areas becomes thready, forming pointed tufts. It contains dry scabs and breaks easily. The general appearance is that of a louse-infested sheep. The skin is hardly altered except that it is covered with dry scales. Microscopically there is a hyperkeratosis and marked desquamation; the deeper layers show round-cell infiltration and sometimes eosinophilia in the immediate vicinity of a parasite. The mites apparently do not penetrate into the skin. The infection spreads very slowly over the body, requiring some 3-4 years to become generalised.

Diagnosis.—Scrapings are taken after moistening the skin with a light mineral oil and directly examined in the oil.

Treatment.—Lime-sulphur dips are effective, while arsenical and carbolic dips are unsatisfactory.

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* *Austral. Vet. Journ.*, 17 (6): 193-201. 1941.

Super-Family TROMBIDOIDEA

Family TROMBIDIIDÆ

This family contains the " harvest mites " or " chigger mites." They usually have a scarlet, red, orange or yellow colour and the adults may be very large. The nymphs and adults are free-living and feed either on invertebrates or plants, but the larvæ are parasitic on various animals and man, causing marked irritation and in some cases they transmit important diseases. The larval mites occur most frequently in autumn and attack grazing animals and human beings working in low-lying fields. The natural hosts of the larvæ are in most cases small rodents such as field-mice. The larval mites attach themselves to the host and suck blood for a few days, after which they drop off and moult to the nymphal stage.

Trombicula autumnalis (Shaw) and other species of this genus attack man and practically all species of domestic animals, including poultry. The latter may be killed by heavy infections. The larger animals are usually attacked on the head and sometimes the neck, where the mites produce an itching dermatitis with loss of hair and scaliness of the skin.

Diagnosis is readily made by finding the red larval mites in scrapings. They have three pairs of legs and the tarsi bear three claws, of which the middle one is the longest. There is a small dorsal shield which bears five hairs. After the mites have dropped off the lesions disappear rapidly.

Treatment.—The mites are easily killed by an application of lime-sulphur dip or other suitable preparation.

Prophylaxis.—The animals should be kept away from infected pastures in the autumn.

T. akamushi (Brumpt) is the Japanese chigger which attacks man and transmits the rickettsia which is the cause of tsutsugamushi disease or river fever. As the latter name indicates, the infection is acquired in low, marshy fields.

Neoschöngastia americana (Hirst) is an injurious parasite of fowls in the Southern United States, while the common North American " chigger," *Leptus rileyi* Oudemans, 1939, attacks man and domestic animals and may cause serious trouble amongst poultry.

Super-Family TARSONEMOIDEA

Family PEDICULOIDIDÆ

Pediculoides ventricosus Newport, the "grain itch mite," is frequently found as a parasite on insects or their young stages that live in grain or straw. From such infected grain the mites may pass on to human beings or domestic animals, which they attack, causing a dermatitis known as "grain itch."

Treatment and Prophylaxis.—The mites on animals can be killed by an application of a suitable dip or disinfectant. Symptomatic treatment to relieve itching may be necessary; for this purpose ichthyol ointment is recommended. When grain and straw are examined before use to determine their suitability, the possible presence of these mites should be remembered. Infected material is best destroyed by burning.

Super-Family DEMODICOIDEA

Family DEMODICIDÆ

Genus **Demodex** Owen, 1843

This is a very specialised group of parasitic mites which live in the hair follicles and sebaceous glands of various mammals, causing demodectic or follicular mange. The parasites which occur on different species of hosts are usually regarded as distinct species, although it is difficult to distinguish between them morphologically, since the main difference is that of size. Most of the species are called after their hosts; for instance, *D. canis*, *D. ovis*, *D. capræ*, etc., while *D. folliculorum* occurs on man and *D. phylloides* on the pig.

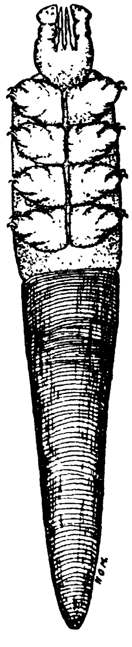

FIG. 273.—*Demodex canis*, VENTRAL VIEW. (ORIGINAL.)

The parasites are elongate, usually about 0·25 mm. long, and they have a head, a thorax which bears four pairs of stumpy legs, and an elongate abdomen which is transversely striated on the dorsal and ventral surfaces. The mouth parts consist of paired palps and chelicerae and an unpaired hypostome. The penis protrudes on the dorsal side of the male thorax and the vulva is ventral in the female. The eggs are spindle-shaped.

Life-Cycle.—This is not well known. The mites develop in the skin of the host where they live. The larva has three pairs of legs and there are apparently three nymphal stages.

The parasites are fairly resistant, being able to survive for several days off the host in moist surroundings. Under experimental conditions the mites lived up to 21 days in pieces of skin that were kept moist and cool.

Epizootology.—Infection is transmitted by direct contact or by mechanical means. Artificial infection is rarely successful, probably because the condition of the host is a strong factor in determining susceptibility. In the case of dogs predisposing factors are youth, short hair, poor condition, debilitating diseases—particularly distemper—and too frequent washing of animals with a tender skin, especially if an alkaline soap is used. It is maintained by some authors that *Demodex* is a very prevalent parasite and occurs in practically all dogs, but produces mange only when the general health and condition are markedly affected as by distemper, or when the skin is weakened by wrong treatment.

Pathogenesis.—The mites enter the hair follicles and sebaceous glands, producing a chronic inflammation with proliferation and thickening of the epidermis and loss of hair. A secondary bacterial invasion, usually by *Staphylococci,* takes place frequently and leads to the formation of pustules or abscesses. The infection spreads over the body by wandering of the parasites, contact of different parts, and on account of wrong treatment. Death is due to toxæmia or emaciation.

Symptoms.—Two forms of the disease are usually recognised. In the scaly form there is loss of hair, thickening and wrinkling of the skin, which becomes scaly and is usually reddened, later becoming bluish-green or acquiring a coppery-red colour. The pustular form is due to bacterial infection and is usually preceded by the scaly form; pustules a few millimetres in diameter develop, or large abscesses may form, and necrotic foci are sometimes seen. The condition does not itch.

In the dog both forms are seen; pustules frequently form on the abdomen, the insides of the legs, the face, the elbows and the feet.

In the pig large abscesses usually develop. In cattle the rump, neck and shoulders are mainly affected with hard, crusty thickenings of the skin, and abscesses may sometimes be seen. In goats the pustular form is the most common. In sheep the disease is rare and usually the scaly form develops. In horses both forms occur. Cats develop lesions like dogs usually on the head, but they are rarely affected.

Diagnosis.—The mites can be found in deep scrapings and in the contents of pustules and abscesses.

Treatment.—Rotenone in a suitable vehicle appears to be the only really satisfactory remedy. Irwin* recommends pure rotenone 5 gm., acetone 125 c.c., olive or cotton-seed oil, or, alternately, alcohol 370 c.c. The oily mixture is preferred except for house dogs treated at home. It is usually best to treat half the body at a time. The mixture has to be applied by massage, and treatment should be repeated every 4-5 days, continuing for 6-8 weeks or, in bad cases, for 5-6 months. Arsenical or other skin tonics should be given. Good food, warmth and exercise are important aids to treatment. Autogenous staphylococcic vaccines may also be useful in the pustular form of the disease.

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* *Vet. Med.*, 32 (7): 318-319. 1937.

CLASS PENTASTOMIDA

This is a group of *Arthropoda* allied to the mites. They occur as internal parasites in the respiratory organs of vertebrates.

The parasites are elongate, often tongue-shaped. The cuticula is transversely striated or sometimes deeply ringed, so that the body may have a beaded appearance in its posterior part. The anterior end is thick, and its flattened ventral surface is armed with two pairs of strong, hooked claws, situated on either side of the elongate oral aperture. The small buccal cavity leads into a pharynx which has a suctorial function, and is followed by an œsophagus, an intestine and a rectum. The anus opens posteriorly. The females are usually larger than the males. As a rule the latter have two elongate testes, and a cirrus sac with a cirrus or penis is present. The male genital opening is situated near the anus. The female has one elongate ovary, but a double ovi-duct which leads into a uterus. The vulva is anteriorly or posteriorly situated. The eggs contain a fully-developed embryo when they are laid.

Life-Cycle.—The egg contains a larva with two or three pairs of rudimentary clawed legs and hatches in the intestine of the intermediate host. The larva bores into the intestinal wall and passes with the blood to the liver and lungs, whence it finds its way into a suitable organ, where it becomes encysted. After several ecdyses, during which the legs are lost, a nymphal stage which is infective for the final host appears. The final host acquires the infection by eating the intermediate host containing the young parasites.

Family POROCEPHALIDÆ

The female genital aperture opens posteriorly. The larva has two pairs of legs.

Genus **Linguatula** Fröhlich

L. serrata Fröhlich, 1779, the "tongue-worm," is a cosmopolitan parasite and occurs in the nasal and respiratory passages of the dog, fox and wolf, more rarely in man, the horse, goat and sheep. The parasite is tongue-shaped, slightly convex dorsally and flattened ventrally. The cuticle is transversely striated. Male 1·8-2 cm., emale 8-13 cm. long. The eggs measure about 90 by 70 μ.

Life-Cycle.—The eggs are expelled from the respiratory passages of the host and, when swallowed by a suitable herbivorous animal such as a horse, sheep, goat, bovine, or rabbit, they hatch in the alimentary canal and the larva reaches the mesenteric lymph glands, in which it develops to the infective nymphal stage. The latter resembles the adult; it is 5-6 mm. long and has a white colour. It usually lies in a small cyst surrounded by a viscid, turbid fluid. Dogs become infected by eating infected rabbits or glands of larger animals.

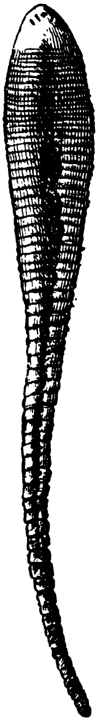

FIG. 274.—*Linguatula serrata*, FEMALE, VENTRAL VIEW. (AFTER NEUMANN.)

Pathogenesis and Symptoms.—The parasites attach themselves high up in the nasal passage and produce a severe irritation which causes the animals to sneeze and cough at intervals. Fits of difficult breathing, uneasiness and restlessness are observed. The animal often rubs its nose with the forefeet and snores in its sleep. A mucous discharge, often blood-stained, may exude from the nostrils. Emaciation may occur unless the animal is well cared for. The parasites live about 15 months, after which the animal usually recovers.

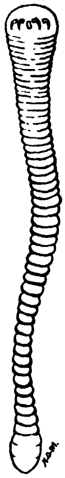

FIG. 275.—*Porocephalus subclavatus*, VENTRAL VIEW. (× 1½.) (ORIGINAL.)

Diagnosis is made from the symptoms and by finding the eggs in the fæces or the nasal discharge.

Treatment is difficult. Injections and inhalations are not very effective. Trephining the nasal passages and removal of the parasites, followed by irrigation if necessary, is the most satisfactory method.

Prophylaxis.—The infection can be avoided by preventing dogs and foxes from eating any possibly infected material.

Species of *Porocephalus* occur in the respiratory passages of large snakes. The body is deeply ringed and may have a beaded appearance posteriorly. The young stages are found in the mesenteric lymph glands and other organs of various wild and domestic animals, including herbivora, carnivora, and man.

HOST PARASITE LIST

THIS list includes only the parasites mentioned in this volume and is therefore not complete. Temporary parasites like blood-sucking *Diptera* are not included, and the ticks are listed only under those hosts which are the most important or to which they transmit diseases.

MAN (*Homo sapiens*).

Dicrocœlium dendriticum
Opistorchis tenuicollis
Opistorchis sinensis
Pseudamphistomum truncatum
Fasciola hepatica
Fasciolopsis buski
Echinostoma revolutum
Echinoparyphium paraulum
Heterophyes heterophyes
Metagonimus yokogawai
Paragonimus westermanii
Troglotrema schikhobalowi
Schistosoma japonicum
Schistosoma hæmatobium
Diphyllobothrium latum
Dipylidium caninum
Tænia solium
Cysticercus cellulosæ
Tænia saginata
Cysticercus bovis
Multiceps multiceps
Multiceps serialis
Echinococcus granulosus (cyst)
Ascaris lumbricoides
Strongyloides stercoralis
Trichinella spiralis
Trichuris trichiura
Syngamus laryngeus
Ancylostoma caninum
Ancylostoma braziliense
Ancylostoma duodenale
Necator americanus
Trichostrongylus colubriformis
Trichostrongylus vitrinus
Trichostrongylus probolurus
Trichostrongylus axei
Mecistocirrus digitatus
Metastrongylus apri
Thelazia callipæda
Gnathostoma spinigerum
Dracunculus medinensis
Dioctophyma renale
Limnatis africana
Gastrophilus intestinalis (larva)
Œstrus ovis (larva)
Hypoderma bovis (larva)
Hypoderma lineata (larva)
Dermatobia hominis (larva)
Cochliomyia hominivorax (larva)
Cordylobia anthropophaga (larva)
Argas persicus
Otobius megnini
Ornithodoros moubata
Hæmaphysalis leporis-palustris
Dermacentor spp.
Sarcoptes scabiei
Liponyssus bacoti
Trombicula spp.
Demodex folliculorum

UNGULATA.

EQUINES (INCLUDING HORSE, MULE AND DONKEY).

Dicrocœlium dendriticum
Fasciola hepatica
Fascioloides magna
Gastrodiscus ægyptiacus
Schistosoma bovis
Schistosoma indicum
Schistosoma japonicum
Schistosoma nasalis
Ornithobilharzia turkestanicum
Anoplocephala magna
Anoplocephala perfoliata
Paranoplocephala mamillana

Multiceps multiceps
Echinococcus granulosus (cyst)
Ascaris equorum
Probstmayria vivipara
Oxyuris equi
Strongyloides westeri
Strongylus equinus
Strongylus edentatus
Strongylus vulgaris
Triodontophorus spp.
Œsophagodontus robustus
Craterostomum spp.
Gyalocephalus capitatus
Poteriostomum spp.
Trichonema spp.
Stephanurus dentatus
Ostertagia ostertagi
Cooperia oncophora
Trichostrongylus axei
Dictocaulus arnfieldi
Habronema muscæ
Habronema microstoma
Habronema megastoma
Gongylonema pulchrum
Thelazia lacrymalis
Parafilaria multipapillosa
Onchocerca cervicalis
Onchocerca reticulata
Setaria equina
Dracunculus medinensis
Dioctophyma renale
Limnatis nilotica
Gastrophilus intestinalis (larva)
Gastrophilus inermis (larva)
Gastrophilus veterinus (larva)
Gastrophilus pecorum (larva)
Gastrophilus hæmorrhoidalis (larva)
Hypoderma bovis (larva)
Hypoderma lineata (larva)
Cochliomyia hominivorax (larva)
Chrysomyia bezziana (larva)
Hippobosca equina
Hippobosca maculata
Hippobosca rufipes
Bovicola equi
Hæmatopinus asini
Otobius megnini
Ixodes ricinus
Boophilus annulatus
Boophilus decoloratus
Margaropus winthemi
Hyalomma ægyptium
Rhipicephalus appendiculatus
Rhipicephalus evertsi
Rhipicephalus bursa
Dermacentor reticulatus
Dermacentor andersoni
Dermacentor nitens
Amblyomma hebræum
Sarcoptes scabiei
Psoroptes communis equi
Chorioptes equi
Trombicula spp.
Linguatula serrata
Linguatula serrata (larva)

SHEEP (*Ovis aries*).

Dicrocœlium dendriticum
Eurytrema pancreaticum
Eurytrema ovis
Fasciola hepatica
Fasciola gigantica
Fascioloides magna
Cymbiforma indica
Paramphistomum cervi
Cotylophoron cotylophorum
Gastrothylax crumenifer
Schistosoma japonicum
Schistosoma bovis
Schistosoma spindalis
Schistosoma indicum
Ornithobilharzia turkestanicum
Moniezia expansa
Moniezia benedeni
Avitellina spp.
Stilesia hepatica
Stilesia globipunctata
Thysanosoma actinioides
Thysaniezia giardi
Cysticercus tenuicollis
Cysticercus ovis
Multiceps multiceps
Echinococcus granulosus (cyst)
Ascaris lumbricoides
Skrjabinema ovis
Skrjabinema alata
Strongyloides papillosus
Trichuris ovis
Trichuris globulosa
Œsophagostomum columbianum
Œsophagostomum venulosum
Chabertia ovina
Syngamus nasicola
Bunostomum trigonocephalum
Gaigeria pachyscelis
Trichostrongylus colubriformis
Trichostrongylus falculatus
Trichostrongylus vitrinus
Trichostrongylus capricola
Trichostrongylus probolurus
Trichostrongylus axei

Trichostrongylus rugatus
Ostertagia ostertagi
Ostertagia circumcincta
Ostertagia trifurcata
Marshallagia spp.
Cooperia curticei
Cooperia punctata
Cooperia pectinata
Cooperia oncophora
Nematodirus spathiger
Hæmonchus contortus
Mecistocirrus digitatus
Dictyocaulus filaria
Protostrongylus rufescens
Neostrongylus linearis
Muellerius capillaris
Gongylonema pulchrum
Gongylonema verrucosum
Gongylonema mönnigi
Thelazia rhodesii
Setaria hornbyi
Limnatis nilotica
Œstrus ovis (larva)
Hypoderma æratum
Hypoderma crossii
Dermatobia hominis (larva)
Lucilia sericata (larva)
Lucilia cuprina (larva)
Calliphora albifrontalis (larva)
Calliphora augur (larva)
Calliphora erythrocephala (larva)
Calliphora fallax (larva)
Calliphora stygia (larva)
Calliphora vomitoria (larva)
Microcalliphora varipes (larva)
Chrysomyia chloropyga (larva)
Chrysomyia albiceps (larva)
Chrysomyia rufifacies (larva)
Chrysomyia micropogon (larva)
Melophagus ovinus
Bovicola ovis
Linognathus ovillus
Linognathus africanus
Linognathus pedalis
Otobius megnini
Ornithodoros moubata
Ixodes ricinus
Ixodes pilosus
Ixodes rubicundus
Boophilus decoloratus
Hyalomma ægyptium
Rhipicephalus appendiculatus
Rhipicephalus evertsi
Dermacentor andersoni
Amblyomma hebræum
Amblyomma variegatum
Sarcoptes scabiei
Psoroptes communis ovis
Psorergates ovis
Trombicula spp.
Linguatula serrata
Linguatula serrata (larva)

GOAT (*Capra hircus*).

Dicrocœlium dendriticum
Eurytrema pancreaticum
Fasciola hepatica
Fasciola gigantica
Cymbiforma indica
Paragonimus westermanii
Paramphistomum cervi
Cotylophoron cotylophorum
Schistosoma japonicum
Schistosoma bovis
Schistosoma spindalis
Schistosoma nasalis
Schistosoma indicum
Ornithobilharzia turkestanicum
Moniezia expansa
Moniezia benedeni
Avitellina spp.
Stilesia hepatica
Stilesia globipunctata
Thysaniezia giardi
Cysticercus tenuicollis
Cysticercus ovis
Multiceps multiceps
Multiceps gaigeri
Echinococcus granulosus (cyst)
Skrjabinema ovis
Strongyloides papillosus
Trichuris ovis
Trichuris globulosa
Œsophagostomum columbianum
Œsophagostomum venulosum
Œsophagostomum asperum
Chabertia ovina
Syngamus nasicola
Bunostomum trigonocephalum
Gaigeria pachyscelis
Trichostrongylus colubriformis
Trichostrongylus falculatus
Trichostrongylus vitrinus
Trichostrongylus capricola
Trichostrongylus axei
Trichostrongylus rugatus
Trichostrongylus retortæformis
Ostertagia circumcincta
Ostertagia trifurcata
Cooperia curticei
Hæmonchus contortus
Dictyocaulus filaria

Protostrongylus rufescens
Neostrongylus linearis
Muellerius capillaris
Gongylonema pulchrum
Gongylonema verrucosum
Gongylonema mōnnigi
Thelazia rhodesii
Thelazia californiensis
Œstrus ovis (larva)
Hypoderma æratum
Hypoderma crossii
Bovicola capræ
Bovicola painei
Bovicola limbatus
Linognathus stenopsis
Otobius megnini
Ixodes pilosus
Ixodes rubicundus
Boophilus decoloratus
Hyalomma ægyptium
Rhipicephalus appendiculatus
Rhipicephalus evertsi
Amblyomma hebræum
Amblyomma variegatum
Sarcoptes scabiei
Psoroptes communis capræ
Trombicula spp.
Demodex capræ
Linguatula serrata
Linguatula serrata (larva)

CATTLE (*Bos taurus*).

Dicrocœlium dendriticum
Dicrocœlium hospes
Eurytrema pancreaticum
Eurytrema cœlomaticum
Fasciola hepatica
Fasciola gigantica
Fascioloides magna
Cymbiforma indica
Paragonimus westermanii
Paramphistomum cervi
Cotylophoron cotylophorum
Gastrothylax crumenifer
Fischœderius cobboldi
Fischœderius elongatus
Carmyerius spatiosus
Carmyerius gregarius
Schistosoma japonicum
Schistosoma bovis
Schistosoma spindalis
Schistosoma nasalis
Schistosoma indicum
Ornithobilharzia turkestanicum
Moniezia expansa
Moniezia benedeni
Avitellina spp.
Stilesia hepatica
Thysanosoma actinioides
Thysaniezia giardi
Cysticercus bovis
Cysticercus tenuicollis
Multiceps multiceps
Echinococcus granulosus (cyst)
Ascaris lumbricoides
Ascaris vitulorum
Strongyloides papillosus
Trichuris ovis
Trichuris globulosa
Œsophagostumum radiatum
Chabertia ovina
Stephanurus dentatus
Syngamus laryngeus
Syngamus nasicola
(?) *Agriostomum vryburgi*
Bunostomum phlebotomum
Trichostrongylus colubriformis
Trichostrongylus axei
Ostertagia ostertagi
Cooperia punctata
Cooperia pectinata
Cooperia oncophora
Nematodirus spathiger
Hæmonchus contortus
Mecistocirrus digitatus
Dictyocaulus viviparus
Gongylonema pulchrum
Gongylonema verrucosum
Thelazia rhodesii
Thelazia gulosa
Thelazia alfortensis
Parafilaria bovicola
Onchocerca gibsoni
Onchocerca gutturosa
Elæophora pœli
Setaria cervi
Stephanofilaria dedœsi
Stephanofilaria stilesi
Stephanofilaria kæli
Stephanofilaria assamensis
Dracunculus medinensis
Dioctophyma renale
Limnatis nilotica
Hypoderma bovis (larva)
Hypoderma lineata (larva)
Dermatobia hominis (larva)
Chrysomyia bezziana (larva)
Cochliomyia hominivorax (larva)
Lyperosia exigua
Lyperosia irritans
Lyperosia minuta
Hippobosca equina

Hippobosca maculata
Hippobosca rufipes
Bovicola bovis
Hæmatopinus eurysternus
Linognathus vituli
Solenopotes capillatus
Otobius megnini
Ixodes ricinus
Ixodes pilosus
Ixodes rubicundus
Boophilus annulatus
Boophilus decoloratus
Boophilus microplus
Boophilus calcaratus
Margaropus winthemi
Hyalomma ægyptium
Hyalomma mauritanicum
Rhipicephalus appendiculatus
Rhipicephalus capensis
Rhipicephalus nitens
Rhipicephalus simus
Rhipicephalus evertsi
Hæmaphysalis cinnabarina punctata
Dermacentor spp.
Amblyomma hebræum
Amblyomma variegatum
Sarcoptes scabiei
Psoroptes communis bovis
Psoroptes natalensis
Chorioptes bovis
Trombicula spp.
Demodex bovis
Linguatula serrata (larva)

PIG (*Sus scrofa domestica*).

Dicrocœlium dendriticum
Opistorchis tenuicollis
Opistorchis sinensis
Fasciola hepatica
Fasciolopsis buski
Echinochasmus perfoliatus
Metagonimus yokogawai
Brachylæmus suis
Paragonimus westermanii
Gastrodiscus ægyptiacus
Schistosoma japonicum
~~*Schistosoma*~~ *suis*
Diphyllobothrium latum
Sparganum raillieti
Cysticercus cellulosæ
~~*Cysticercus tenuicollis*~~
Echinococcus granulosus (cyst)
Ascaris lumbricoides
Strongyloides westeri
Strongyloides ransomi
Strongyloides suis
Trichinella spiralis
Trichuris trichiura
Bourgelatia diducta
Œsophagostomum dentatum
Stephanurus dentatus
Ancylostoma duodenale
Necator suillus
Globocephalus spp.
Trichostrongylus colubriformis
Trichostrongylus axei
Hyostrongylus rubidus
Ollulanus tricuspis
Mecistocirrus digitatus
Metastrongylus apri
Metastrongylus pudendotectus
Metastrongylus salmi
Ascarops strongylina
Ascarops dentata
Physocephalus sexalatus
Simondsia paradoxa
Gongylonema pulchrum
Gnathostoma hispidum
Setaria congolensis
Suifilaria suis
Dioctophyma renale
Macracanthorhynchus hirudinaceus
Limnatis nilotica
Gastrophilus spp. (larva)
Cochliomyia hominivorax (larva)
Hæmatopinus suis
Boophilus decoloratus
Sarcoptes scabiei
Demodex phylloides

CARNIVORA.

DOG (*Canis familiaris*).

Dicrocœlium dendriticum
Opistorchis tenuicollis
Opistorchis sinensis
Pseudamphistomum truncatum
Fasciola hepatica
Fasciolopsis buski
Echinochasmus perfoliatus
Heterophyes heterophyes
Metagonimus yokogawai
Paragonimus westermanii
Troglotrema salmincola
Schistosoma japonicum
Schistosoma spindalis
Schistosoma suis

Diphyllobothrium latum
Diphyllobothrium mansoni
Mesocestoides lineatus
Dipylidium caninum
Cysticercus cellulosæ
Tænia hydatigena
Tænia pisiformis
Tænia ovis
Tænia krabbei
Tænia multiceps
Tænia gaigeri
Tænia serialis
Echinococcus granulosus
Echinococcus granulosus (cyst)
Toxascaris leonina
Toxocara canis
Strongyloides stercoralis
Trichinella spiralis
Trichuris vulpis
Capillaria hepatica
Capillaria aerophila
Ancylostoma caninum
Ancylostoma braziliense
Uncinaria stenocephala
Necator americanus
Trichostrongylus colubriformis
Angiostrongylus vasorum
Filaroides osleri
Spirocerca lupi
Spirocerca arctica
Physaloptera rara
Physaloptera canis
Thelazia callipæda
Thelazia californiensis
Gnathostoma spinigerum
Dirofilaria immitis
Dirofilaria repens
Acanthocheilonema dracunculoides
Microfilaria grassii
Microfilaria ochmanni
Microfilaria reconditum
Microfilaria auquieri
Microfilaria lewisi
Dracunculus medinensis
Dioctophyma renale
Oncicola canis
Limnatis nilotica
Limnatis africana
Gastrophilus spp. (larva)
Dermatobia hominis (larva)
Cordylobia anthropophaga (larva)
Hippobosca capensis
Trichodectes canis
Heterodoxus longitarsus
Linognathus setosus
Ctenocephalides canis
Echidnophaga gallinacea
Otobius megnini
Ixodes ricinus
Ixodes holocyclus
Boophilus decoloratus
Rhipicephalus simus
Rhipicephalus sanguineus
Rhipicephalus bursa
Hæmaphysalis leachi
Hæmaphysalis bispinosum
Dermacentor variabilis
Sarcoptes scabiet
Otodectes cynotis
Pneumonyssus caninum
Demodex canis
Linguatula serrata

CAT (*Felis domestica*).

Platynosomum concinnum
Opistorchis tenuicollis
Opistorchis sinensis
Pseudamphistomum truncatum
Fasciola hepatica
Echinochasmus perfoliatus
Euparyphium melis
Heterophyes heterophyes
Metagonimus yokogawai
Paragonimus westermannii
Schistosoma japonicum
Ornithobilharzia turkestanicum
Diphyllobothrium latum
Diphyllobothrium mansoni
Mesocestoides lineatus
Dipylidium caninum
Joyeuxiella spp.
Diplopylidium spp.
(?) *Tænia hydatigena*
Tænia pisiformis
Tænia tæniæformis
Echinococcus granulosus
Echinococcus granulosus (cyst)
Toxascaris leonina
Toxocara mystax
Strongyloides stercoralis
Strongyloides cati
Trichinella spiralis
Eucoleus aerophilus
Ancylostoma caninum
Ancylostoma braziliense
Uncinaria stenocephala
Ollulanus tricuspis
Ælurostrongylus abstrusus
Physaloptera præputialis
Physaloptera canis
Physaloptera felidis
Thelazia californiensis

Gnathostoma spinigerum
Dirofilaria immitis
Dermatobia hominis (larva)
Felicola subrostrata
Ctenocephalides felis
Echidnophaga gallinacea
Otobius megnini
Ixodes holocyclus
Hæmaphysalis leachi
Notœdres cati
Otodectes cynotis

Fox (*Vulpes vulpes*).

Opistorchis tenuicollis
Pseudamphistomum truncatum
Echinochasmus perfoliatus
Euparyphium melis
Heterophyes heterophyes
Euryhelmis squamula
Paragonimus westermanii
Troglotrema acutum
Troglotrema salmincola
Diphyllobothrium latum
Mesocestoides lineatus
Dipylidium caninum
Tænia pisiformis
Tænia ovis
Tænia tæniæformis
Tænia multiceps
Tænia serialis
Echinococcus granulosus
Toxascaris leonina
Toxocara canis
Strongyloides stercoralis
Trichinella spiralis
Trichuris vulpis
Capillaria plica
Capillaria aerophila
Ancylostoma caninum
Ancylostoma braziliense
Uncinaria stenocephala
Ollulanus tricuspis
Angiostrongylus vasorum
Crenosoma vulpis
Spirocerca lupi
Spirocerca arctica
Dirofilaria immitis
Dracunculus medinensis
Dioctophyma renale
Linognathus setosus
Ctenocephalides canis
Sarcoptes scabiei
Otodectes cynotis
Linguatula serrata

Badger (*Meles meles*).

Euparyphium melis
Eucoleus aerophilus
Physaloptera spp.

Otter (*Lutra lutra*).

Euparyphium melis
Dioctophyma renale

Beech Marten (*Martes foina*).

Euparyphium melis
Paragonimus westermanii
Mesocestoides lineatus
Capillaria entomelas
Eucoleus aerophilus
Dioctophyma renale

Pine Marten (*Martes martes*).

Euparyphium melis
Paragonimus westermanii
Tæmia hydatigena
Eucoleus aerophilus
Dioctophyma renale

Mink (*Lutreola vison*).

Euparyphium melis
Euryhelmis squamula
Euryhelmis monorchis
Paragonimus westermanii
Troglotrema acutum
Troglotrema salminlcoa
Mesocestoides lineatus
(?) *Strongyloides papillosus*
Capillaria entomelas
Gnathostoma spinigerum
Dracunculus medinensis
Diotcophyma renale

Polecat (*Putorius putorius*).

Euparyphium melis
Euryhelmis squamula
Troglotrema acutum
Tænia hydatigena

Capillaria entomelas
Gnathostoma spinigerum
Diotcophyma renale

Stoat (*Mustela erminea*).

Tænia hydatigena
Tænia tæniæformis

Ascaris columnaris

Weasel (*Mustela nivalis*).

Clonorchis sinensis
Euparyphium melis
Euryhelmis squamula

Tænia hydatigena
Ascaris columnaris

Skunk (*Mephitis mephitis*).

Ascaris columnaris

Raccoon (*Procyon lotor*).

Troglotrema salmincola

Dracunculus medinensis

RODENTS.

Rabbit (*Oryctolagus cuniculus*).

Dicrocœlium dendriticum
Fasciola hepatica
Schistosoma japonicum
Cittotænia ctenoides
Cittotænia denticulata
Cittotænia pectinata
Cysticercus pisiformis
Multiceps serialis
Echinococcus granulosus (cyst)
Passalurus ambiguus
Strongyloides papillosus
Trichinella spiralis
Capillaria hepatica

Trichostrongylus vitrinus
Trichostrongylus retortæformis
Graphidium strigosum
Protostrongylus rufescens
Physocephalus sexalatus
Thelazia callipæda
Dermatobia hominis (larva)
Cordylobia anthropophaga (larva)
Sarcoptes scabiei
Notœdres cati
Psoroptes communis cuniculi
Linguatula serrata (larva)

Beaver (*Castor fiber*).

Fasciola hepatica

Coypu (*Myocaster coypus*).

Dicrocœlium dendriticum
Fasciola hepatica
Anoplocephalid

Multiceps serialis
(?) *Strongyloides papillosus*

Muskrat (*Ondatra zibethica*).

Paragonimus westermanii
Cysticercus fasciolaris

Capillaria hepatica

Squirrel (*Sciurus vulgaris*).

Cysticercus tenuicollis
Cysticercus fasciolaris

Multiceps serialis
Capillaria hepatica

HAMSTER (*Circetus circetus*).

Cysticercus tenuicollis

BIRDS.

FOWL (*Gallus gallus*).

Echinostoma revolutum
Echinoparyphium recurvatum
Hypoderæum conoideum
Prosthogonimus pellucidus
Prosthogonimus ovatus
Plagiorchis arcuatus
Notocotylus attenuatus
Catatropis verrucosa
Brachylæmus commutatum
Collyriclum faba
Dithyridium variabile
Davainea proglottina
Raillietina tetragona
Raillietina echinobothrida
Raillietina cesticillus
Cotugnia digonopora
Amœbotænia sphenoides
Choanotænia infundibulum
Metroliasthes lucida
Hymenolepis carioca
Fimbriaria fasciolaris
Heterakis gallinæ
Heterakis brevispiculum
Heterakis beramporia
Heterakis indica
Ascaridia galli
Subulura brumpti
Subulura differens
Strongyloides avium
Capillaria longicollis
Capillaria columbæ
Capillaria annulata
Syngamus trachea
Trichostrongylus tenuis
Hartertia gallinarum
Gongylonema ingluvicola
Gongylonema crami
Acuaria hamulosa
Acuaria spiralis
Tetrameres americana
Tetrameres fissispina
Physaloptera truncata
Oxyspirura mansoni
Oxyspirura parvorum
Polymorphus boschadis
Cochliomyia hominivorax (larva)
Menopon gallinæ
Eomenacanthus stramineus
Lipeurus heterographus
Lipeurus caponis
Goniocotes gigas
Goniocotes hologaster
Ceratophyllus gallinæ
Echidnophaga gallinacea
Argas persicus
Hyalomma ægyptium
Hæmaphysalis cinnabarina
Amblyomma hebræum
Cnemidocoptes gallinæ
Cnemidocoptes mutans
Cytoleichus nudus
Laminosioptes cysticola
Dermanyssus gallinæ
Liponyssus bursa
Liponyssus bacoti
Liponyssus sylviarum
Neoschöngastia americana

TURKEY (*Meleagris gallopavo*).

Brachylæmus commutatum
Collyriclum faba
Dithyridium variabile
Raillietina cesticillus
Choanotænia infundibulum
Metroliasthes lucida
Heterakis gallinæ
Ascaridia galli
Subulura brumpti
Strongyloides avium
Capillaria columbæ
Capillaria contorta
Capillaria annulata
Syngamus trachea
Trichostrongylus tenuis
Acuaria hamulosa
Acuaria spiralis
Tetrameres americana
Tetrameres fissispina
Oxyspirura mansoni
Eomenacanthus stramineus
Goniodes meleagridis
Argas persicus
Hyalomma ægyptium
Cnemidocoptes mutans
Cytoleichus nudus
Dermanyssus gallinæ
Liponyssus bursa

PIGEON (*Columba livia domestica*).

Echinoparyphium paraulum
Echinoparyphium recurvatum
Hypoderæum conoideum
Brachylæmus commutatum
Apatemon gracilis
Cotylurus cornutus
Davainea proglottina
Raillietina tetragona
Cotugnia cuneata
Ascaridia columbæ
Capillaria columbæ
Capillaria longicollis
Ornithostrongylus quadriradiatus
Acuaria spiralis
Tetrameres fissispina
Pseudolynchia canariensis
(?) *Menopon gallinæ*
Goniocotes hologaster
Columbicola columbæ
Argas persicus

GUINEA-FOWL (*Numida meleagris*).

Brachylæmus commutatum
Raillietina tetragona
Raillietina cesticillus
Heterakis gallinæ
Ascaridia galli
Subulura brumpti
Subulura differens
Syngamus trachea
Trichostrongylus tenuis
Acuaria spiralis

PEA-FOWL (*Pavo cristatus*).

Raillietina tetragona
Heterakis gallinæ
Oxyspirura mansoni
Menopon phæostomum
Eomenacanthus stramineus

DUCK (*Anas boschas domestica*).

Opistorchis simulans
Echinostoma revolutum
Echinoparyphium paraulum
Echinoparyphium recurvatum
Hypoderæum conoideum
Prosthogonimus pellucidus
Notocotylus attenuatus
Catatropis verrucosa
Typhlocœlum cymbium
Typhlocœlum obovale
Hyptiasmus tumidus
Apatemon gracilis
Parastrigea robusta
Cotylurus cornutus
Bilharziella polonica
Cotugnia fastigata
Hymenolepis lanceolata
Fimbriaria fasciolaris
Porrocæcum crassum
Heterakis gallinæ
Heterakis dispar
Ascaridia galli
Capillaria contorta
Cyathostoma bronchialis
Amidostomum anseris
Trichostrongylus tenuis
Acuaria uncinata
Tetrameres fissispina
Tetrameres crami
Hystrichis tricolor
Polymorphus boschadis
Filicollis anatis
(?) *Menopon gallinæ*
Argas persicus

GOOSE (*Anser anser domesticus*).

Echinostoma revolutum
Hypoderæum conoideum
Notocotylus attenuatus
Catatropis verrucosa
Hyptiasmus tumidus
Hymenolepis lanceolata
Fimbriaria fasciolaris
Heterakis gallinæ
Heterakis dispar
Ascaridia galli
Syngamus trachea
Cyathostoma bronchialis
Amidostomum anseris
Trichostrongylus tenuis
Acuaria uncinata
Polymorphus boschadis
Filicollis anatis
Argas persicus

Swan (*Cygnus olor domesticus*).

Hypoderæum conoideum
Cyathostoma bronchialis
Acuaria uncinata
Polymorphus boschadis
Filicollis anatis

Ostrich (*Struthio* spp.).

Houttuynia struthionis
Codiostomum struthionis
Libyostrongylus douglassii
Argas persicus
Otobius megnini
Hyalomma ægyptium

INDEX

Abida frumentum, 37
Abramis brama, 45
Acanthocephala, 266
Acanthocheilonema dracunculoides, 257
Acarida, 276, 297, 358
    mouth parts, 287
Acephalous, 292
Acuaria (Cheilospirura) hamulosa, 244
    (Dispharynx) spiralis, 245
    (Echinuria) uncinata, 246
Acuariidæ, 244
Aedes, 256, 301, 305
Ægyptionella pullorum, 359
Ælurostrongylus abstrusus, 229
Agriolimax, 103, 229, 230, 232
Agriostomum vryburgi, 194
Air-sac mite, 396
Aleurobius farinæ, 297
Allergic reactions, 28
Alula, 288
Amblyomma, 376
    americanum, 377
    cayennense, 377
    hebræum, 376
    variegatum, 377
American dog tick, 376
Amidostomidæ, 201
Amidostomum anseris, 201
    nodulosum, 201
Amnicola, 63
Amœbotænia sphenoides, 107
Amphid, 131
Amphidelph, 133
Amphipepla cumingiana, 46
Amphistoma conicum, 74
Ampullaria luteostoma, 68
Anal vein, 288
Anaplasma centrale, 365, 367
    marginale, 365, 367, 368, 372, 374, 375, 376
Ancylostoma braziliense, 191
    caninum, 190
    ceylanicum, 191
    duodenale, 191
Ancylostomidæ, 190
Angiostrongylus vasorum, 230
Anisakinæ, 144
Anisotarsus agilis, 113
Annelida, 272
Anopheles, 256, 257, 301
Anoplocephala magna, 95
    perfoliata, 95
Anoplocephalidæ, 95
Anoplura, 275, 349
Antenna, 278
Anthrax, 47, 298, 307, 334, 345
Antisquama, 288
Apatemon gracilis, 78
Aphodius, 107, 113, 240, 243
Apodeme, 282
Aponomma, 377
Aptera, 275
Arachnida, 276, 358
Araneida, 276
Arduenna strongylina, 240
Arduennidæ, 240
Argas persicus, 359
Argasidæ, 358
Argentine tick, 369
Arianta, 232
Arion, 103, 229, 232
Arista, 278
Armadillidum vulgare, 245
Arthropoda, 275
Ascaridæ, 136
Ascaridia columbæ, 149
    galli, 147
    lineata, 147
    maculosa, 149
    perspicillum, 147
Ascaris columnaris, 141
    equorum, 140
    lumbricoides, 136
    megalocephala, 140
    ovis, 136
    suis, 136
    vitulorum, 139
Ascaroidea, 135
Ascaropidæ, 240
Ascarops dentata, 240
    strongylina, 240
Asellus aquaticus, 268
Astacus dauricus, 68
    japonicus, 68
    similis, 68
Avicularoidea, 296
Avitellina, 99
    centripunctata, 99

Baber's fly trap, 319
Babesia bigemina, 368, 372, 373, 374
  bovis, 365, 368
  caballi, 370, 375
  canis, 372, 374, 375
  gibsoni, 374
  motasi, 373
  ovis, 373
  trautmanni, 368
Baermann funnel, 27
Barbus puckelli, 264
Basis capituli, 287
Bedbug, 348
Bee stings, 294
Beef measles, 118
Belascaris marginata, 142
Bilharziella polonica, 86
Bithynia leachi, 42
  species, 42
Black disease, 47
  flies, 299
  widow spider, 296
Blackhead, 146
Black scours worm, 205
Bladderworm, 90
Blatella germanica, 243, 247, 297
Blatta orientalis, 298
Blicca björkna, 42, 45
Blind flies, 305
Blood-worms, 299
Blowflies, 321
Blue louse, 354
  tick, 368
  tongue, 299
Body louse, 351
Bont-leg tick, 369
Bont tick, 376
Boophilus, 367
  annulatus, 368
  australis, 368
  calcaratus, 368
  decoloratus, 368
  microplus, 368
Booponus intonosus, 332
Bot, 308
Bothridia, 91
Botulism, 321
Bourgelatia diducta, 174
Bovicola bovis, 352
  capræ, 352
  equi, 352
  limbatus, 352
  ovis, 352
  painei, 352
Brachylæmidæ, 66
Brachylæmus commutatum, 66
  suis, 67
Brood capsules, 90
Brown dog tick, 372
  stomach worm, 210
  tick, 370
Brown-tail moth, 294
Bubulcus ibis, 380
Buffalo fly, 335
  gnat, 299
Bulinus contortus, 84
  schakoi, 74
  striatulus japonicus, 65
  tropicus, 46, 74
  truncatus, 84
  verreauxi, 74
Bunostomum phlebotomum, 198
  trigonocephalum, 196
Buphagus africanus, 380
  erythrorhynchus, 380
Bursa, 163
Bursal rays, 163
Bursati, 235

Calathus, 107
Calliphora albifrontalis, 321
  augur, 321
  erythrocephala, 321
  fallax, 321
  novica, 321
  stygia, 321
  vomitoria, 321
Calliphorinæ, 321
Calliphorine myiasis, 322
Camerostoma, 287
Canalis gynæcophorus, 80
Cantharidin, 295
Capillaria aerophila, 162
  annulata, 161
  columbæ, 161
  contorta, 161
  entomelas, 160
  hepatica, 161
  longicollis, 161
  plica, 161
Capitulum, 287
Carbon tetrachloride, 50
Carcass disposal, 329
Cardo, 279
Carmyerius gregarius, 76
  spatiosus, 76
Cascado, 263
Casoni reaction, 28
Castor-bean tick, 365
Catatropis verrucosa, 65
Cattle-dipping tank, 381
Cepea, 103, 232
Cephalopharyngeal skeleton, 318
Cephalothorax, 287
Ceratophyllus fasciatus, 357
  gallinæ, 358

Ceratopogon, 299
Cercaria, 34
  classification, 36
  frondosa, 74
  pigmentata, 74
  vitrina, 37
Cercocystis, 90
Cestoda, definition, morphology, 87
  development, 89
Chabertia ovina, 183
Cheliceræ, 276
Chigger mite, 400
Chilopoda, 293
Chiracanthrium nutrix, 297
Chironomidæ, 299
Chitin, 277
Choanotænia infundibulum, 107
Chœridium histeroides, 113
Chœrostrongylus pudendotectus, 225
Chorioptes bovis, 395
  equi, 394
Chrysomyia albiceps, 321
  bezziana, 322, 330
  chloropyga, 321
  marginalis, 324
  micropogon, 321
  rufifacies, 321
Chrysops, 306
Cimex lectularius, 348
Cimicidæ, 293, 348
Cirrus, 33, 89
  sac, 33, 89
Cittotænia ctenoides, 98
  denticulata, 99
  pectinata, 99
Clarias batrachus, 253
Cleopatra, 78
Clonorchis sinensis, 42
Clypeus, 277
Cnemidocoptes gallinæ, 386
  mutans, 386
Coarctate, 292
Cochliomyia americana, 322, 330
  hominivorax, 322, 330
Cockroaches, 297
Codiostomum struthionis, 174
Cœnurus cerebralis, 122
Coleoptera, 276, 298
Collyriculum faba, 69
Columbicola columbæ, 352
Commensalism, 3
Conical fluke, 74
Cooperi curticei, 212
  oncophora, 213
  pectinata, 213
  punctata, 212
Coracidium, 89
Cordylobia anthropophaga, 331
Coretus corneus, 56, 57, 65, 87
Costa, 288
Cotugnia cuneata, 105
  digonopora, 105
  fastigata, 105
Cotylophoron cotylophorum, 74
Cotylurus cornutus, 79
Coxa, 289
Craterostomum, 168
Creeping eruption, 194
  myiasis, 309
Crenosoma vulpis, 232
Croton bug, 297
Crustacea, 275
Crutching, 329
Ctenocephalides canis, 110, 356
  felis, 110, 356
Cubital vein, 288
Culex, 256, 305
Culicidæ, 301
Culicoides austeni, 299
  nubeculosus, 260, 299
  pungens, 259, 299
Cutaneous habronemiasis, 235
Cyathostoma bronchialis, 190
Cyclocœlidæ, 72
Cyclophyllidea, 94
Cyclops, 253, 264
  strenuus, 92
Cyclorrhapha, 278, 281
Cylicostomum, 168
Cymbiforma indica, 66
Cysticercoid, 90
Cysticercus, 90
  bovis, 117
  cellulosæ, 115, 262
  fasciolaris, 122
  ovis, 121
  pisiformis, 121
  tarandi, 122
  tenuicollis, 119
Cytodites nudus, 396
Cytoleichidæ, 396
Cytoleichus nudus, 396

Daphnia pulex, 246, 248
Dasypus novemcinctus, 271
Daughter cysts, endogenous, 127
    exogenous, 127
Davainea proglottina, 103
Davaineidæ, 102
DDT, 320
Demodex bovis, 401
  canis, 401
  capræ, 401
  folliculorum, 401
  phylloides, 401
Demodicidæ, 401

Demodicoidea, 401
Dendrobæna, 225
Depluming itch, 386
Dermacentor, 374
    albipictus, 376
    andersoni, 295, 366, 375
    nitens, 376
    occidentalis, 376
    parumapertus marginatus, 376
    reticulatus, 375
    variabilis, 376
    venustus, 375
Dermanyssidæ, 397
Dermanyssus gallinæ, 397
Dermatobia cyaniventris, 316
    hominis, 316
Diaptomus gracilis, 92
    vulgaris, 114
Dichoptic, 277
Dicrocœliidæ, 37
Dicrocœlium dendriticum, 37
    hospes, 38
    lanceolatum, 37
Dictyocaulus arnfieldi, 224
    filaria, 220
    viviparus, 223
Digenea, 34
Dilepididæ, 106
Dioctophyma renale, 264
Dioctophymidæ, 264
Dioctophymoidea, 264
Dipetalonema perstans, 287
Diphyllobothriidæ, 91
Diphyllobothrium latum, 91
    mansoni, 94
Diplocardia, 225
Diplopoda, 293
Diplopylidium, 112
Dipping of cattle, 378
    of sheep, 392
    tank, 378, 392
Diptera, 276
Dipylidium caninum, 109, 358
Dirofilaria immitis, 255
    repens, 257
Discal sclerite, 282
Dithyridium, 90
    variabile, 95
Dog tick, 373
Dorsal gutter, 164
Dracunculus medinensis, 263

Ear mange, 395
Earthworm, 107, 225
East Coast fever, 370, 372, 373
Echidnochasmus perfoliatus, 58
Echidnophaga gallinacea, 358
Echinococcus, 90
Echinococcus alveolaris, 127
    granulosus, 125
    multilocularis, 127
Echinoparyphium paraulum, 55
    recurvatum, 56
Echinorhynchidæ, 267
Echinorhynchus gigas, 269
    minutus, 267
    polymorphus, 267
Echinostoma columbæ, 55
    revolutum, 54
Echinostomatidæ, 54
Ectoparasite, 3
Eisenia, 225
Elæophora pœli, 260
Eliocharis tuberosa, 53
Empodium, 289
Ena obscura, 37
Encephalomyelitis, equine, 305, 375
Endoparasite, 3
Endoskeleton, 277
Eomenacanthus stramineus, 351
Eosinophilia, 5
Epeiridæ, 297
Epipharynx, 279
Epiphragmophora, 230
Erinaceus europæus, 59
Eriocheir japonicus, 68
    sinensis, 68
Eucephalous, 292
Eucoleus aerophilus, 162
Euomphalia strigella, 37
Euparyphium melis, 59
Euryhelmis squamula, 61
    monorchis, 62
Eurytrema cœlomaticum, 40
    ovis, 40
    pancreaticum, 39
Eustrongylus gigas, 264
Exanthematic fever, 370, 372, 374
Exoskeleton, 277

Fæces examination, 16
Fannia, 324
Fasciola gigantica, 51
    hepatica, 45
Fasciolidæ, 45
Fascioloides magna, 52
Fasciolopsis buski, 52
Fat body, 290
Felicola subrostrata, 352
Femur, 289
Filaria hæmorrhagica, 258
Filariidæ, 255
Filaroidea, 254
Filaroides osleri, 231
Filicollis anatis, 268
Fimbriaria fasciolaris, 113

- Fischœderius cobboldi, 76
  - elongatus, 76
- Fistulous withers, 260
- Flame cell, 32
- Flea, 356
- Flesh fly, 307
- Fluff louse, 352
- Follicular mange, 401
- Foot louse, 355
  - maggot, 332
  - mange, 395
  - rot, 155, 199
- Fossaria modicella, 46, 52, 74
  - ollula, 46, 51
  - parva, 52, 74
- Fowl pox, 305
  - tick, 359
- Fringed tapeworm, 101
- Frons, 277
- Fulcrum, 282

- Gaigeria pachyscelis, 199
- Galba bulimoides, 46
  - cubensis, 46
  - ferruginea, 46
  - techella, 46, 52, 74
  - truncatula, 46
- Galea, 279
- Galeodes, 276
- Gall sickness, see Anaplasma
- Galumna, 96
- Gambusia holbrooki, 305
- Gammarus fasciatus, 248
  - pulex, 248, 268
- Gapeworm, 187
- Gastrodiscus ægyptiacus, 77
- Gastrophilus equi, 308
  - hæmorrhoidalis, 308
  - inermis, 308
  - intestinalis, 308
  - nasalis, 308
  - pecorum, 308
  - veterinus, 308
- Gastrothylax crumenifer, 75
- Gena, 277
- Genal comb, 356
- Genital cone, 163
- Geotrupes sylvaticus, 107, 241
- Gid, 123
- Gigantorhynchidæ, 269
- Globocephalus, 200
- Glossa, 279
- Glossina development, 338
  - brevipalpis, 340
  - morsitans, 339
  - mouth parts, 284
  - pallidipes, 339
  - palpalis, 339
- Glossina tachinoides, 336
- Glossininæ, 336
- Glossogobius giurus, 253
- Glyciphagus domesticus, 297
- Gnathobdellæ, 272
- Gnathostoma hispidum, 253
  - spinigerum, 252
- Gnathostomidæ, 252
- Gongylonema crami, 244
  - hominis, 242
  - ingluvicola, 244
  - mönnigi, 244
  - neoplasticum, 244
  - pulchrum, 242
  - scutatum, 242
  - verrucosum, 244
- Goniobasis plicifera silicula, 71
- Goniocotes gigas, 352
  - hologaster, 352
- Goniodes meleagridis, 352
- Gordiacea, 266
- Grain-itch mite, 401
- Granular dermatitis, 235
- Graphidium strigosum, 206
- Gubernaculum, 133
- Guinea worm, 263
- Gular region, 277
- Gyalocephalus capitatus, 168
- Gymnopleurus, 240, 241

- Habronema megastoma, 234
  - microstoma, 233, 334
  - muscæ, 233
- Hæmadipsa, 274
- Hæmaphysalis, 373
  - bispinosum, 374
  - cinnabarina, 374
    - punctata, 374
  - humerosa, 374
  - leachi, 373
  - leporis palustris, 374
- Hæmatopinidæ, 354
- Hæmatopinus asini, 354
  - eurysternus, 354
  - suis, 354
- Hæmatopota, 306
- Hæmocœle, 290
- Hæmonchus contortus, 215
- Hæmopis sanguisuga, 78
- Hæmoproteus columbæ, 348
- Hæmostrongylus vasorum, 230
- Hairballs, 356
- Halteres, 288
- Harmostomidæ, 66
- Harmostomum, 66
- Hartertia gallinarum, 236
- Harvest mite, 400
- Haustellum, 282

Head louse, 351
Heartwater, 377
Helicella candidula, 37
    ericetorum, 37
    itala, 37
    species, 227
Helisoma, 55, 73
Helix, 229, 230, 232
Helminthoglypta, 230
Helodrilus caliginosus, 162, 225
    fœtidus, 162, 225
Hemicephalous, 292
Hemiptera, 276, 348
    mouth parts, 285
Hepatitis cysticercosa, 120
Hepatozoon canis, 372
Herpobdella atomaria, 78
Heterakidæ, 145
Heterakis beramporia, 146
    brevispiculum, 146
    dispar, 146
    gallinæ, 145
    indica, 146
    isolonche, 4
    papillosa, 145
    putaustralis, 146
    vesicularis, 145
Heterodoxus longitarsus, 352
Heterophyes heterophyes, 60
Heterophyidæ, 59
Hexacanth embryo, 89
Hexylresorcinol, 144
Hippobosca mouth parts, 285
    capensis, 346
    equina, 344
    francilloni, 346
    maculata, 344
    rufipes, 344
Hippoboscidæ, 344
Hirudinacea, 272
Hirudo medicinalis, 272
Hister species, 113
Histomonas meleagridis, 146
Hodge's garbage can trap, 320
Holoptic, 278
Hookworm, 190
Hoose, 223
Hornfly, 335
Horse fly, 305
    sickness, 299
Host, definitive, 3
    final, 3
    intermediate, 3
    natural, 5
Hour-glass spider, 296
Houttuynia struthionis, 105
Hump sore, 263
Hunterellus, 380
Husk, 223
Hyalella knickerbockeri, 248
Hyalomma, 369
    ægyptium, 369
    anatolicum, 370
    detritum, 370
    dromedarii, 370
    marginatum, 370
    mauritanicum, 370
    savignyi, 370
Hydatid, 126
    sand, 126
Hymenolepididæ, 112
Hymenolepis carioca, 113
    lanceolata, 113
    nana, 90
Hymenoptera, 276, 294
    parasitic, 306, 325, 330, 341, 380
Hyostrongylus rubidus, 207
Hypoderæum conoideum, 57
Hypoderma æratum, 316
    bovis, 313
    crossii, 316
    lineata, 313
Hypopharynx, 279
Hypopygium, 289
Hypostome, 287
Hyptiasmus tumidus, 73
Hystrichis tricolor, 266

Idus melanotis, 42
Immunity, 6
Indoplanorbis exustus, 74, 85
Infectious anæmia, equine, 307, 334
Insecta, 275, 297
    cryptotoxic, 295
    nettling, 294
    piercing or biting, 293
    stinging, 294
Instar, 292
Itchy leg, 395
Ixodes, 295, 365
    holocyclus, 367
    pilosus, 366
    ricinus, 365
    rubicundus, 367
    scapularis, 367
Ixodidæ, 363
Ixodiphagus, 380
Ixodoidea, 358

Jetting, 329
Joyeuxiella, 112

Kala-azar, 301
Kathlaniidæ, 150
Ked, 346
Kidney worm, 184
Killing bottle, 14

Labella, 280
Labial gutter, 280
Labium, 279
Labrum, 279
Lacinia, 279
Lactophenol, 14
Laminosioptes cysticola, 397
Latrodectus mactans, 296
Laurer's canal, 33
Leaf-crown, 131
Leeches, 272
Leishmania donovani, 301
Lemnisci, 266
Lepidoptera, 276
Leptus rileyi, 400
Leuciscus rutilus, 42, 45
Leucocytozoon anatis, 300
    caulleryi, 300
    smithi, 300
Libellula quadrimaculata, 63
Libyostrongylus douglassii, 209
Limax, 103, 229
Limberneck, 321
Limnæa acuminata, 46, 51, 85
    attenuata, 55
    brazieri, 46
    bulimoides, 46
    japonica, 46
    limosa, 65
    luteola, 85
    natalensis, 46, 51
    ovata, 56, 57
    palustris, 65
    peregra, 55, 57
    pervia, 46
    philippensis, 46
    stagnalis, 55, 56, 57, 79
    swinhœi, 46, 55
    tenera euphratica, 86
    traskii, 46
    truncatula, 46
    viatrix, 46
Limnatis africana, 273
    nilotica, 273
Limnotragus spekei, 83
Linguatula serrata, 403
Linognathus africanus, 354
    ovillus, 354
    pedalis, 354
    piliferus, 354
    setosus, 354
    stenopsis, 354
    vituli, 354
Lipeurus baculus, 352
    caponis, 352
    heterographus, 351
Liponyssus bacoti, 397
    bursa, 397
Liponyssus sylviarum, 397
Liver fluke, 45
Loa loa, 256
Lone-star tick, 377
Longitudinal lines, 130
Louping ill, 365, 372
Louse, 349
Lucilia cuprina, 321
    sericata, 321
Lumbricus rubellus, 225
    terrestris, 225
Lung fluke, 67
Lungworms, 220
Lycosa tarantula, 296
Lyperosia exigua, 335
    irritans, 335
    minuta, 335

MacLean County System, 139
Macracanthorhynchus hirudinaceus, 269
Macrohodothermes mossambicus, 237
Mallophaga, 350
    mouth parts, 286
Malpighian tube, 290
Mandible, 279
Mange, 382, 384, 394
    scrapings, 16
Mansonia, 305
Manure, disposal of, 319
Margaropus, 369
    winthemi, 369
Marshallagia, 212
Maxilla, 279
Mecistocirrus digitatus, 219
Median vein, 288
Mehli's gland, 33, 89
Melania, 42, 61
Melanoplus differentialis, 247
    femurrubrum, 247
Meloidæ, 295
Melolontha vulgaris, 270
Melophagus ovinus, 346
Menopon biseriatum, 351
    gallinæ, 351
    pallidum, 351
    phæostomum, 351
Mentum, 279
Mermithida, 266
Meromyarian, 130
Mesocestoides lineatus, 94
Mesocestoididæ, 94
Metacercaria, 35
Metagonimus yokogawai, 61
Metastrongylidæ, 220
Metastrongylus apri, 224
    brevivaginatus, 225
    elongatus, 224
    pudendotectus, 225

Metastrongylus salmi, 225
Metaterm, 33
Metroliasthes lucida, 112
Microcalliphora varipes, 321
Microfilaria, 254
    diagnosis, 256
    periodicity, 254
    acutiuscula, 256
    auquieri, 256
    dracunculoides, 256
    grassii, 256
    immitis, 256
    lewisi, 256
    ochmanni, 256
    reconditum, 256
Midge, 299
Miracidium, 34
Mite, 382
Mites in foodstuffs, 297
Monezia benedeni, 96
    expansa, 96
Moniliformis moniliformis, 271
Monodontus, 196
Monogenea, 34
Mormoniella vitripennis, 325
Mosquito, 301
    mouth parts, 281
Muellerius capillaris, 228
Mugil cephalus, 60
    japonicus, 60
Multiceps, 90
    gaigeri, 125
    multiceps, 122
    serialis, 125
Murrina, 319
Musca domestica, 107, 234, 317
    mouth parts, 282
Muscidæ, 316
Muscinæ, 317
Mutualism, 3
Myiasis, 308
Myriapoda, 275, 293
Myxas ampulla, 46
Myzorhynchus, 256

Nagana, 336
Nairobi sheep disease, 372, 377
Nanophyetus salmincola, 70
Nasal granuloma, 85
Nasonia brevicornis, 325
Necator americanus, 195
    suillis, 195
Nematoda, definition, 130
    development, 134
    morphology, 130
Nematodirus filicollis, 214
    spathiger, 214
Nematomorpha, 266
Neoschöngastia americana, 400
Neostrongylus linearis, 228
Neuroptera, 275
Nodular worm, 175
Notocotylidæ, 65
Notocotylus attenuatus, 65
Notœdres cati, 382, 387
Numenius arquatus, 63
Nuttallia equi, 370, 372, 373

Obtectate, 292
Ocelli, 278
Œsophagodontus robustus, 168
Œsophagostomum asperum, 182
    columbianum, 175
    dentatum, 182
    radiatum, 182
    venulosum, 182
Œstridæ, 308
Œstrus ovis, 311
Olfactory pit, 278
Ollulanus tricuspis, 219
Onchocerca cervicalis, 260
    gibsoni, 258
    gutturosa, 260
    reticulata, 260
Oncomelania formosana, 81
    hupensis, 81
    nosophora, 81
    quadrasi, 81
Oncorhynchus, 71
Oncosphere, 89
Oncicola canis, 270
Onthophagus, 240, 241, 243
Oötype, 33, 89
Ophiocephalus striatus, 253
Opisthodelph, 133
Opistorchiidæ, 41
Opistorchis felineus, 41
    simulans, 42
    sinensis, 42
    tenuicollis, 41
Oribatid mites, 87
Oriental roach, 298
Ornithobilharzia bomfordi, 86
    turkestanicum, 86
Ornithocoris toledoi, 349
Ornithodoros moubata, 362
    savignyi, 362
Ornithostrongylus quadriradiatus, 208
Orthoptera, 275
Orthorrhapha, 278, 280, 298
Oslerus osleri, 231
Ostertagia circumcincta, 211
    ostertagi, 211
    trifurcata, 211
Otobius megnini, 360
Otodectes cynotis, 395

Otodectic mange, 395
Ovipositor, 289
Owl midges, 301
Ox warbles, 313
Oxyspirura mansoni, 251
  parvorum, 251
Oxyuridæ, 150
Oxyuris curvula, 150
  equi, 150
  mastigodes, 150

Pangonia, 306
Papatasi fever, 301
Paraffin emulsion, 360
Parafilaria bovicola, 258
  multipapillosa, 258
Parafossalurus striatulus, 42
Paraglossa, 279
Paragonimus kellicotti, 67
  ringeri, 67
  westermanii, 67
Paralysis tick, 366
Paramphistomidæ, 73
Paramphistomum cervi, 74
Paranoplocephala mamillana, 96
Parascaris equorum, 140
Parasite, erratic, 4
  facultative, 4
  incidental, 4
  obligatory, 4
  periodic, 4
  permanent, 4
  temporary, 4
Parasitism, 2
Parasitoidea, 397
Parastrigea robusta, 78
Parenchyma, 32
Parenchymatous capsule, 89
Paruterine organ, 89
Passalurus ambiguus, 152
Pasteurella tularensis, 374, 375
Pediculoides ventricosus, 401
Pediculoididæ, 401
Pedipalpi, 276
Pentastomida, 403
Periodicity, 254
Peritrophic membrane, 290
Peronia, 324
Phagocytic cell, 131
Phanæus, 241
Pheidole, 104
Phenothiazine, 171
Phlebotomus papatasi, 301
Phormia terræ-novæ, 322
Physa, 46, 55
Physaloptera canis, 249
  felidis, 249
  præputialis, 248
Physaloptera rara, 249
Physalopteridæ, 248
Physocephalus sexalatus, 240
Physopsis africana, 46, 51, 84
  globosa, 84
Pieris brassicæ, 295
Pirenella conica, 60
Plagiorchidæ, 62
Plagiorchis arcuatus, 64
Planorbis corneus, 56, 57, 65, 87
  planorbis, 56, 74
  rotundatus, 65
  species, 53, 73, 79, 85
  tenuis, 55
Plasmodium, 305
Platynosomum concinnum, 39
  fastosum, 39
Plerocercoid, 92
Pleura, 277
Pneumonyssus caninum, 398
Poll evil, 260
Polymorphus boschadis 267
Polymyarian, 130
Pomatiopsis lapidaria, 62, 68
Porcellio lævis, 245
  scaber, 245
Pork measle, 115
Porocephalidæ, 403
Porocephalus, 404
Porrocæcum crassum, 145
Porthesia chrysorrhœa, 294
Potamobius astacus, 268
Potamon dehaani, 68
  obtusipes, 68
  sinensis, 68
Poteriostomum, 168
Præscutum, 288
Preservation of parasites, 13
Prestomal teeth, 283
Prestomum, 279
Proboscis, 266, 272
Probstmayria vivipara, 150
Procercoid, 92
Prodelph, 133
Proglottis, 87
Prosthogonimus intercalandus, 62
  macrorchis, 63
  ovatus, 64
  pellucidus, 62
Protostrongylus rufescens, 226
Pseudamphistomum truncatum, 44
Pseudolynchia canariensis, 347
Pseudophyllidea, 91
Pseudoscolex, 114
Pseudosuccinia columella, 46, 52, 74
Pseudotelphusa iturbei, 68
Pseudotracheal membrane, 280, 283
Psorergates ovis, 399

Psoroptes communis bovis, 394
    capræ, 394
    cuniculi, 394
    equi, 394
    natalensis, 394
    ovis, 388
Psychodidæ, 301
Ptilinal sac, 278
Pulex irritans, 110, 358
Pulvillus, 289
Pupipara, 334
  development, 291
Pycnoscelus surinamensis, 251
Pyriform apparatus, 95

Q fever, 362, 372, 374

Rabbit tick, 374
Rabies, 116, 143, 257, 271
Radial vein, 288
Radix ovata, 56, 57
  peregra, 55, 57
Raillietina cesticillus, 105
  echinobothrida, 104
  tetragona, 103
Rana clamitans, 62
  esculenta, 58
  palustris, 62
  pipiens, 62
  temporaria, 57, 62
Redia, 34
Red mite, 397
  tick, 372
Reduviidæ, 293
Redwater, 365
Resistance, 6
Rhabditidæ, 152
Rhabditiform œsophagus, 152
Rhabditis strongyloides, 153
Rhipicentor, 376
Rhipicephalus, 371
  appendiculatus, 371
  bursa, 373
  capensis, 372
  evertsi, 372
  sanguineus, 372
  simus, 372
Rhynchobdellæ, 272
Rickettsia bovis, 370
  burneti, 372, 374
  canis, 372
  conori, 370, 372, 374
  diaporica, 362
  ovina, 373
  ruminantium, 377
Rift Valley fever, 305
Rocky Mountain spotted fever, 372, 374, 375, 376, 377

Rostellum, 88
Rostrum, 282
Russet tick, 366

Salmo species, 71
Salmon poisoning, 71
Salvelinus fontinalis, 71
Sandflies, 301
Sarcophaga, 307
Sarcophagidæ, 307
Sarcoptes scabiei, 382
Sarcoptic mange, 384
Sarcoptidæ, 382
Sarcoptoidea, 382
Scab, 387
Scaly leg, 386
Scape, 278
Scarabeus, 238, 241
Scardinius erythrophthalmus, 45
Scheloribates, 96
Schistosoma bovis, 83
  hæmatobium, 83
  incognitum, 86
  indicum, 86
  japonicum, 80
  matthei, 83
  nasalis, 85
  spindalis, 85
  suis, 86
Schistosomatidæ, 80
Scolex, 87
Scolopendra gigantea, 293
Scorpionida, 276, 295
Screw-worm flies, 321, 330
Scutellum, 288
Scutum, 288
Seed ticks, 363
Segmentina, 53
Sesarma dehaani, 68
Setaria bernardi, 262
  cervi, 262, 334
  congolensis, 262
  equina, 261
  hornbyi, 262
  labiato-papillosa, 262
Shaft louse, 351
Sheep ked, 346
  nasal fly, 311
  scab, 387
Shell gland, 33
Simondsia paradoxa, 242
Simuliidæ, 299
Simulium, 300
  ornatum, 300
  venustum, 300
Siphonaptera, 276
  mouth parts, 285
Siphunculata, 353

Siphunculata, mouth parts, 286
Skrjabinema alata, 152
  ovis, 152
Sleeping sickness, 336
Snails, destruction of, 51
Snoring disease, 85
Solenopotes capillatus, 354
Solpugida, 276, 295
Spanish fly, 295
Sparganum, 93
  raillieti, 94
Specificity, 5
Sphærium corneum, 55
Spicule, 133
Spider, 295
Spinose ear tick, 360
Spiracle, 289
Spirocerca arctica, 240
  lupi, 237
  sanguinolenta, 237
Spirochæta anserina, 305, 359, 398
  duttoni, 362
  theileri, 368, 373
Spiruridæ, 233
Spiruroidea, 233
Sporocyst, 34
Squama, 288
Stable fly, 333
Stagnicola, 46, 52, 59, 79
Stegomyia, 257
Stephanofilaria assamensis, 263
  dedœsi, 263
  kæli, 263
  stilesi, 263
Stephanurus dentatus, 184
Sterna, 277
Stick-tight flea, 358
Stigmata, 289
Stilesia globipunctata, 101
  hepatica, 100
Stipes, 279
Stomach worm, 215
Stomoxinæ, 333
Stomoxys calcitrans, 234, 262, 333
  mouth parts, 282
Strigeidæ, 78
Strobila, 87
Strongylidæ, 164
Strongyloidea, 163
Strongyloides avium, 154
  cati, 154
  papillosus, 153
  ransomi, 154
  stercoralis, 27
  suis, 154
  westeri, 154
Strongylus edentatus, 166
  equinus, 164
Strongylus vulgaris, 167
Sturdy, 123
Subcosta, 288
Subcutaneous mite, 397
Submentum, 279
Subulura brumpti, 149
  differens, 150
Succinea, 229
Suifilaria suis, 262
Summer sores, [illegible]5
Surra, 307, 334
Swine fever, 356
  influenza, 226
Symbiosis, 3
Syngamus laryngeus, 190
  nasicola, 190
  trachea, 187

Tabanidæ, 305
Tabanus, 306
  mouth parts, 280
Tæniasis in dogs and cats, 110
  in poultry, 108
Tænia crassicollis, 121
  gaigeri, 125
  hydatigena, 119
  krabbei, 122
  marginata, 119
  multiceps, 122
  ovis, 121
  pisiformis, 121
  saginata, 117
  serialis, 125
  serrata, 121
  solium, 114
  tæniæformis, 121
Tæniidæ, 114
Tampan, 362
Tapeworms, 87
Tarantula, 296
Tarsonemoidea, 401
Tarsus, 289
Telamon, 133
Terga, 277
Tetrachlorethylene, 50
Tetragoneuria, 63
Tetrameres americana, 247
  crami, 248
  fissispina, 248
Tetramorium cæspitum, 104
  semilæve, 104
Texas fever, 368
Theba carthusiana, 37
Theileria annulata, 368, 370, 372
  dispar, 370
  mutans, 372, 373
  ovis, 373
  parva, 370, 372, 373

- Thelazia alfortensis, 250
  - californiensis, 251
  - callipæda, 250
  - gulosa, 250
  - lachrymalis, 250
  - rhodesii, 250
- Thelaziidæ, 250
- Therapon argenteus, 253
- Thysaniezia giardi, 102
- Thysanosoma actinioides, [illegible]01
- Tibia, 289
- Tick-borne fever, 365
- Tick paralysis, 375
- Tinca tinca, 42
- Tongue-worm, 403
- Toxascaris leonina, 142
  - limbata, 142
- Toxocara canis, 142
  - mystax, 142
- Tracheæ, 289
- Tracheophilus sisowi, 72
- Trapa bicornis, 53
  - natans, 53
- Trematoda, definition, morphology, 31
  - development, 34
- Triboleum, 107
- Trichina spiralis, 156
- Trichinella spiralis, 156
- Trichinellidæ, 156
- Trichinelloidea, 155
- Trichocephalus, 158
- Trichodectes canis, 110, 352
  - climax, 352
  - latus, 352
  - parumpilosus, 352
  - scalaris, 352
  - sphærocephalus, 352
- Trichonema, 168
- Trichostrongylidæ, 202
- Trichostrongylus axei, 203
  - capricola, 203
  - colubriformis, 202
  - extenuatus, 203
  - falculatus, 203
  - instabilis, 202
  - probolurus, 203
  - retortæformis, 206
  - rugatus, 203
  - tenuis, 205
  - vitrinus, 203
- Trichuris apri, 159
  - dispar, 159
  - globulosa, 159
  - ovis, 158
- Trichuris suis, 159
  - trichiura, 159
  - vulpis, 159
- Triodontophorus, 167
- Trochanter, 289
- Troglotrema acutum, 70
  - salmincola, 70
  - schikhobalowi, 71
- Troglotrematidæ, 67
- Trombicula akamushi, 400
  - autumnalis, 400
- Trombidiidæ, 400
- Trombidoidea, 400
- Tropical fowl mite, 397
  - rat mite, 397
- Tropisternus collaris, 270
- Trypanosoma brucei, 341
  - congolense, 341
  - evansi, 307, 334
  - gambiense, 341
  - hippicum, 319
  - melophagium, 347
  - rhodesiense, 342
  - theileri, 307, 345
  - vivax, 342
- Tsetse fly, 336
- Tsutsugamushi disease, 400
- Tularemia, 374, 375, 376
- Tumbu fly, 331
- Tumours, 4, 85, 231, 234, 238
  - malignant, 4, 42, 122, 244
- Typhlocœlum cymbium, 72
  - obovale, 73

- Uncinaria stenocephala, 192
- Uterine bell, 267

- Variegated tick, 377
- Vertex, 277
- Vivipara vivipara, 55, 56

- Whipworm, 158
- Wing of arthropod, 288
  - louse, 352
  - venation, 288
- Wireworm, 215
- Wohlfahrtia euvittata, 308
  - vigil, 308
- Wuchereria bancrofti, 256

- Xerophila, 67

- Zebrina detrita, 37

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